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Hangman (Latah) Creek Watershed Fecal Coliform, Temperature, and Turbidity Total Maximum Daily Load

Water Quality Improvement Report

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SCCD
Spokane County Conservation District
Bringing People and Resources Together

DEPARTMENT OF ECOLOGY
State of Washington

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For more information contact:

Water Quality Program
Regional/HQ
Office Address
City, WA zip
Phone: Section secretary phone number

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Project Codes

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TMDL Study Code (Water Quality Program) is HCWS56MP.

Cover photo: Hangman Creek in the canyon-like reach north of Keevey Road (photo by Walt Edelen, Spokane County Conservation District)

Hangman (Latah) Creek Watershed Fecal Coliform, Temperature, and Turbidity Total Maximum Daily Load

Water Quality Improvement Report

by:

Joe Joy
Environmental Assessment Program
Washington State Department of Ecology
Olympia, Washington 98504-7710

Rick Noll
Water Resources Program
Spokane County Conservation District
Spokane, Washington 99202

Elaine Snouwaert
Water Quality Program – Eastern Regional Office
Washington State Department of Ecology
Spokane, Washington 98205-1295

Waterbody Numbers:
WA-56-1010, Hangman Creek
WA-56-2040, Rock Creek

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List of Figures

WQP will format these Figure and Table lists

Note to WQP from EAP: Joe would like these figures printed in color: 4, 20, 32, and 39
Elaine would like Table 27, Figure 40 and 42 in color.

List of Tables

Abstract

This *Water Quality Improvement Report*, also called a Total Maximum Daily Load (TMDL) report, was a coordinated effort of the Spokane County Conservation District, the Washington State Department of Ecology, local landowners, agencies, organizations, and citizen groups. The Hangman Creek watershed is a cross-border watershed with approximately 35% in Idaho. Water quality activities on the Coeur d'Alene Indian Reservation and on Idaho lands will be important to the success of this water quality improvement project.

Hangman (Latah) Creek is on Washington State's list of impaired waterbodies (the 303(d) list) for fecal coliform, pH, temperature, dissolved oxygen, and turbidity. In addition, the draft *Spokane River Dissolved Oxygen TMDL* recommends limits on phosphorus loads coming from Hangman Creek. Phosphorus delivery from Hangman Creek is associated with suspended sediments and turbidity. This TMDL does not address phosphorus limits or dissolved oxygen and pH impairments in the watershed.

The Clean Water Act requires states to establish a TMDL for each waterbody and parameter on the 303(d) list. Using data collected from 1998 through 2006, this report analyzes how much fecal coliform, heat, and suspended solids loads Hangman Creek and its tributaries can assimilate and meet water quality standards. This report lists strategies for how to reduce pollutant loads where necessary.

There are six wastewater treatment facilities and three regulated stormwater dischargers in the Hangman Creek watershed. Each will receive wasteload allocations to control point (discrete) source pollution. Nonpoint (diffuse) source pollution will be controlled by meeting recommended load allocations geographically throughout the watershed.

This report emphasizes best management practices (BMPs) and education that target continuing nonpoint source problems, such as the high fecal coliform bacteria, erosion, and lack of streamside vegetation. The BMPs, and other alternatives discussed in this improvement plan, should help to reduce nutrients and alleviate other 303(d) listed problems in the Hangman Creek watershed.

Acknowledgements

The fieldwork and community outreach by the Spokane County Conservation District (SCCD) were funded by the Washington State Department of Ecology (Ecology) through a Centennial Clean Water Fund Grant for the Hangman Creek TMDL assessment (grant number G0400196). Charlie Peterson, Dan Ross, Amy Voeller, and Jennifer McCall of SCCD spent many hours in the field setting up the sampling sites, surveying the cross-sections, and organizing the field equipment.

The outcome of this report, including many of the ideas and suggestions, can be directly associated to the significant help from several watershed residents:

- Bill Sayres was instrumental in forming one of the first meetings with small-scale landowners along Hangman Creek.
- Charlie Johnson provided insight to many of the issues in the watershed and was at the forefront in organizing meetings involving livestock owners in the watershed.
- Pat and Jennie Kane provided valuable insight to our issues from the perspective of long-time farmers.
- Gary Ostheller shared a historical perspective that helped the Hangman Creek Advisory Committee gain an appreciation and understanding of the agricultural operations in the watershed.
- Micki Harnois bestowed upon our committee the insight of the many small towns in the watershed.
- Cathy McBeth brought to the committee insights from a newcomer to the area with the ambition and resources to try new and innovative ideas in working the land.
- Layne Merritt of Century West, Inc. provided valuable information about the operations and challenges of the small treatment plants in the watershed.

Many thanks also to the following people for their contributions to this study:

- The watershed agencies that provided input and ideas: Dee Bailey and Scott Fields with the Coeur d'Alene Tribe, Reanette Boese and Ben Brattebo with Spokane County, and Bill Rickard with the City of Spokane.
- Region 10 of the U.S. Environmental Protection Agency for funding the landscape modeling and technical support. Dave Ragsdale of that office for his reviews, comments, and advice through the TMDL process.
- Scott Coffey, Steve Wolosoff, and Tom Quasebarth of Camp, Dresser, McKee, Inc. for developing the WARMF model for the Hangman Creek watershed.
- The Town of Fairfield which made our meetings exceedingly pleasant. It is a busy town and is characterized by a spirit of enterprise. A considerable acreage of wheat and other cereals is raised in this vicinity, and the future of this progressive little town is sure to be prosperous.

- David Moore of Ecology's Water Quality Program and Stephanie Brock and Paul Pickett of Ecology's Environmental Assessment Program for reviewing and providing comments on this report.
- Joan LeTourneau, Gayla Lord, and Cindy Cook of Ecology's Environmental Assessment Program, as well as Donna Ward from Ecology's Water Quality Program, for formatting and editing this document.

Executive Summary

How about adding a section about Gov to Gov cooperation between WA and the Coeur d'Alene Tribe? I suggest this because it was only via this successful collaboration that Ecology can presume (with support from the upstream jurisdiction) improved conditions at the state border as boundary conditions in your TMDL. This TMDL is precedential in doing this and it is well worth highlighting. Also, we do not want it to appear that there is any intention to hide that improved upstream conditions are incorporated into the pollutant loading strategy of this TMDL.

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What is a Total Maximum Daily Load (TMDL)?

The federal Clean Water Act established a process to identify and clean up polluted waters. Each state is required to have water quality standards designed to protect, restore, and preserve water quality. Every two years, states are required to prepare a list of waterbodies that do not meet water quality standards. This list is called the 303(d) list.

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each pollutant of the waterbodies on the 303(d) list. A TMDL is the highest amount (or load) of a pollutant a surface waterbody can receive and still meet water quality standards. The difference between the TMDL and the current amount of pollutant coming from point (discrete) and nonpoint (diffuse) sources is how much pollution needs to be reduced or eliminated to achieve clean water. The Washington Department of Ecology (Ecology), local governments, agencies, and the community develop a strategy to control the pollution and a monitoring plan to assess effectiveness of the water quality improvement activities.

Why is Ecology Conducting a TMDL Study in this Watershed?

Hangman Creek (also known as Latah Creek) is a trans-boundary watershed that begins in the foothills of the Rocky Mountains of northern Idaho, extends over the southeastern portion of Spokane County, Washington (Figure 1), and is a tributary to the Spokane River. It encompasses over 689 square miles (approximately 441,000 acres). The TMDL allocations are limited to the 446 square miles of watershed within Washington, although some TMDL success depends on upstream controls on the Coeur d'Alene Reservation and Idaho.

The watershed is dominated by dryland farming, but like other eastern Washington watersheds, is experiencing increases in urbanization and changes in land use practices. The watershed contains remnant populations of genetically distinct redband trout and other native and introduced fish species.

Ecology and the Spokane County Conservation District (SCCD) are developing TMDLs because several parts of Hangman Creek were identified on the 1998 303(d) list of impaired waters for not meeting state water quality standards for fecal coliform, dissolved oxygen, pH, and temperature. Hangman Creek and several of its tributaries (Little Hangman Creek, Rattler Run Creek, and Rock Creek) were also included on the 2004 303(d) list of impaired water for not achieving state water quality standards for fecal coliform, dissolved oxygen, turbidity, and temperature (Table ES1). Additional data collected for this study have identified other water quality impairments that are proposed for the 2006/2008 303(d) list.

In addition to developing TMDLs specific to the Hangman Creek watershed, a phosphorus load allocation has been recommended for Hangman Creek by the draft *Spokane River/Lake Spokane Dissolved Oxygen TMDL.* The Spokane River and Lake Spokane exhibit depressed dissolved oxygen (DO) levels during low flow in the summer months. Phosphorus loads from Hangman Creek and other sources in the Spokane River basin contribute to algae growth in the lake that eventually depress oxygen levels. Since phosphorus is often attached to suspended sediment, efforts to reduce turbidity may help increase Spokane River DO.

Table ES1. Hangman Creek watershed reaches on the 2004 303(d) list.

Waterbody Name	Listed Parameter	Listing Identification Number
Hangman Creek	Fecal Coliform	16862
		16863
		6726
		41992
	Turbidity	40942
Little Hangman Creek	Fecal Coliform	41994
	Turbidity	40940
Rattler Run Creek	Turbidity	40941
Rock Creek	Fecal Coliform	41996
Hangman Creek	Temperature	3736
Rock Creek	Turbidity	40943

Goals and Objectives

The goal of this TMDL is to develop a plan to meet water quality standards for fecal coliform bacteria, temperature, and turbidity in Hangman Creek and its tributaries. The following technical analysis and *Implementation Strategy* will accomplish this goal by:

1. Characterizing fecal coliform bacteria, heat, and suspended sediment loading from various parts of the basin.
2. Incorporating previously conducted temperature modeling work into a temperature TMDL.

3. Setting of (TMDL) allocations on fecal coliform, temperature, and suspended sediment/turbidity.
4. Outlining an *Implementation Strategy*

Originally, this TMDL study also included a phosphorus load analysis from Hangman Creek to the Spokane River. The loading analysis used the same methods and models as this report's turbidity and suspended sediment TMDL analysis. The phosphorus analysis is not included in this report because it did not explore the role of phosphorus in causing pH or dissolved oxygen criteria violations in the Hangman watershed. A dissolved oxygen, pH, and nutrient TMDL for Hangman Creek will be completed in 2009–2010.

Study Methods

Ecology used field data from historical and current studies conducted by the SCCD, Ecology, and others to develop the TMDLs. Most of the historical data were collected in the 1990s and early 2000s. Recent sampling by the SCCD for the development of this study included 19 sites on Hangman Creek and its tributaries. Sampling occurred from December 2003 through August 2004. All Ecology and SCCD samples were collected under approved quality assurance project plans. Data quality objectives in all studies were reviewed, evaluated, and met.

In 2002 Hardin-Davis, Inc., with assistance from SCCD, monitored and modeled Hangman Creek water temperature under a separate watershed study. Recognized methods of field data collection were used and documented. The model used was the Stream Network Temperature Model (SNTEMP), an analytical tool supported by the U.S. Fish and Wildlife Service and U.S. Geological Survey. The Hardin-Davis study data were used as a starting point for the temperature TMDL analysis in this report. Ecology completed the analysis with additional shade modeling and water temperature data evaluations.

Several statistical methods were used on the temperature, fecal coliform, turbidity, and suspended sediment data. Statistical tests were run using WQHYDRO® (Aroner, 2007) and Microsoft Office Excel® (2003) software. For example, the fecal coliform TMDL analysis was based on a statistical approach called the Statistical Rollback Method (Ott, 1995) and another statistical method for calculating annual load estimates. Suspended solids evaluations were performed using a multiple regression analytical method by Cohn (1988) with SYSTAT® software.

The Watershed Analysis Risk Management Framework (WARMF) model was used to evaluate suspended sediment loading from all types of land uses and sources in the watershed. The initial Hangman Creek watershed model was developed by Cadmus and CDM through an EPA Region 10 grant (Cadmus Group, Inc. and CDM, 2007). The software is supported by the EPA Office of Environmental Research and originally developed by the Systech Corporation (Systech, 2001). With additional data from local agencies, Ecology further calibrated the model to observed water quality data and developed scenarios for future sediment control practices. Model output from current and future scenarios were compared for the likelihood that aquatic life, including trout populations, would be harmed by the duration and intensity of suspended sediment events.

TMDL Analyses

Fecal coliform bacteria

Washington State uses fecal coliform bacteria as an indicator of a creek's suitability for direct contact. Many areas in Hangman Creek watershed have fecal coliform counts posing a health risk to swimmers, fisherman, and others. The health threats are not constant, but bacteria load reductions are necessary to reduce the risk of illness.

The Statistical Rollback Method (Ott, 1995) was used to determine how much fecal coliform needed to be reduced at individual sites to meet the water quality criteria. The estimated wasteload allocations for point source pollution and load allocations for nonpoint sources in the watershed are shown in Tables ES2 and ES3, respectively.

Because bacteria counts are especially high during storm events, most of the sources are probably nonpoint runoff from farms, towns, and residential areas. Storm events cause high counts in all seasons. Some wastewater treatment plants (WWTPs) had poor disinfection practices in the past that have recently improved. The WWTP bacteria limits are based on their current NPDES permits, or have been adjusted to protect public health by reducing the risk of waterborne illness. According to more recent Ecology records, all WWTPs are in compliance with the target reductions recommended in Table ES2.

Table ES2. Fecal coliform wasteload allocations for point sources discharging to Hangman Creek and its tributaries.*

Point Source	Wasteload Allocation (10^8 cfu/day)[1]	Current Load[2] (10^8 cfu/day)	Target Reduction[4] (percent)
Tekoa WWTP[3]	31	140	78
Fairfield WWTP	18	90	80
Rockford WWTP	20	47	57
Freeman School District WWTP	1.6	1.9	16
Spangle WWTP	6.6	2.2	0.0
Cheney WWTP	100	–	0.0
WSDOT[6] Stormwater	NC[4]	NC	72
Spokane County Stormwater	NC	NC	72
City of Spokane Stormwater	NC	NC	72

* According to the most recent monitoring records, the WWTPs are in compliance with these fecal coliform target reductions.

[1] 10^8 cfu/day is 100,000,000 colony forming units per day.

[2] Current load calculated on 2003-2004 data

[3] WWTP is wastewater treatment plant.

[4] Target reductions assume the National Pollutant Discharge Elimination System (NPDES) permit has a monthly effluent geometric mean limit of 100 cfu/100 mL and a weekly maximum of 200 cfu/100 mL. For stormwater, the target basis is less than 10 % of the samples are greater than 200 cfu/100 mL (cfu/100 mL is colony forming units per 100 milliliters).

[5] NC is not calculated.

[6] WSDOT is Washington State Department of Transportation.

Table ES3. Fecal coliform load allocations for Hangman Creek reaches and tributaries.

Reach Name	Load Allocation (10^8 cfu/day)[1]	Current Load (10^8 cfu/day)	Target Reduction (percent)
Hangman Creek at State Line (Road)	5,600	20,000	72
Little Hangman Creek	560	1700	67
Hangman Creek at river mile 53.8[2]	6,200	22,000	72
Hangman Creek at Fairbanks Rd	2,400	5,400	56
Hangman Creek at Spring Valley Rd	2,800	8,000	65
Hangman Creek at Marsh Rd	3,300	4,900	32
Cove Creek	13	60	79
Unnamed tributary at Griffith Rd	3.0	4.1	25
Unnamed tributary at Roberts Rd	1.5	3.0	61
Hangman Creek at Roberts Rd	5,100	7,000	27
Hangman Creek at Bradshaw Rd	6,800	17,000	60
Rattler Run Creek at the mouth[3]	23	150	85
Rattler Run Creek nonpoint	5	60	92
Hangman Creek at Keevy Rd	3,700	17,000	78
Hangman Creek at river mile 21.4	2,900	6,700	56
Rock Creek at the mouth	660	2,200	70
Rock Creek at Jackson Rd	2,400	7,500	68
Rock Creek at Rockford	240	740	67
Spangle Creek at the mouth[3]	8.6	12	28
Spangle Creek nonpoint	2.0	10	80
Hangman Creek at Duncan	7,000	7,800	10
California Creek at the mouth	25	32	23
California Creek at Marsh Rd	7.1	14	49
Marshall Creek at the mouth	8.3	18	54
Marshall Creek at McKenzie Rd	30	30	0.0
Hangman Creek at mouth	230	820	72

[1] 10^8 cfu/day is 100,000,000 colony forming units per day.
[2] River mile is the number of miles upstream from the mouth of Hangman Creek.
[3] Nonpoint load allocations for Spangle and Rattler Run Creeks are the total allowed loads from nonpoint sources. The load allocations at the mouths of these creeks include the nonpoint allocation and the WWTP.

The following conclusions and recommendations are based on this fecal coliform bacteria TMDL evaluation:

Conclusions

- Bacteria loads at the mouth of Hangman Creek appear to be decreasing over the long-term, but this may be a result of declining streamflows rather than declining fecal coliform counts.
- Fecal coliform counts exceed one or both parts of the Washington State criteria at several locations in the watershed at various times throughout the year, but no location appeared to be chronically contaminated.
- Storm events at any time of the year result in elevated bacteria counts in many reaches of the watershed, and are the main cause of criteria violations that require TMDL load reductions.
- The sources of bacteria contamination in the watershed are not obvious, but may include livestock access to banks and water, malfunctioning on-site septic systems, faulty or aged WWTP disinfection systems, waterfowl and wildlife, and stormwater runoff.
- Disinfection practices at some WWTPs have improved over the past few years and now consistently comply with NPDES permit limits.
- Implementing a 72% bacteria load reduction at the mouth of Hangman Creek during July through September should be adequate to reduce bacteria loads throughout the year if actions are taken that treat low-flow and high-flow sources of contamination. Other reaches and tributaries require bacteria loads to be reduced by 10% to 85%.

Recommendations

- The mouth of Hangman Creek and reaches where informal swimming occurs should be the highest priority areas for bacteria abatement action.
- Ecology will need to work with EPA, the Coeur d'Alene Tribe, and Idaho to reduce bacteria loads in upper Hangman Creek, Little Hangman Creek, and Rock Creek.
- Most sites require more sampling to better identify sources of bacteria and seasonal patterns, especially where livestock, wildlife, and waterfowl sources are suspected.
- Direct livestock access to riparian areas should be limited to prevent fecal wastes from directly or indirectly entering the waterways.
- Limiting Tekoa WWTP effluent fecal coliform counts to a monthly geometric mean of 100 cfu/100 mL and a weekly geometric mean of 200 cfu/100 mL would ensure downstream criteria are met during low-flow conditions.
- As required by the Municipal Phase 2 Stormwater NPDES Permit, permit holders must map their stormwater systems. If any stormwater entity determines that a stormwater outfall may be contributing bacteria to surface water, they should notify Ecology permit managers and work cooperatively to ensure fecal coliform reductions are achieved.
- All possible sources of fecal coliform should be addressed through source best management practices (BMPs).

Temperature

The temperature TMDL is built from work previously conducted for the Hangman Creek Watershed Planning Unit under the Watershed Planning process. Hardin-Davis (2003) collected temperature and streamflow data with assistance from the SCCD. They used the data for a Stream Network Temperature (SNTEMP) model. SNTEMP simulates average and maximum daily temperatures along a stream under steady-state flow conditions (USGS, 2006). The model included 34.5 river miles from Hays Road to the mouth of Hangman Creek.

The SNTEMP model is a well-known tool for evaluating the effects of shade, water volumes, and channel alterations on average and maximum temperatures in moving water. The Hardin-Davis (2003) work demonstrated that average temperatures could not meet the 17.5ºC water quality criterion under current stream conditions. Small increases in flow (3 cfs) or an increase in shade from current average shade conditions of 20% to shade of 70% did not lower water temperatures enough to meet the criterion.

To meet TMDL requirements, additional analysis in this report was necessary to provide site-specific recommendations for increased shade along the creek, and to evaluate effluent temperature limits for some WWTPs. Ecology conducted additional geographic information system (GIS) and modeling analyses using three specialized software tools:

- Oregon Department of Environmental Quality's Ttools extension for ArcView (ODEQ, 2001) was used to sample and process GIS data for the Shade model.
- Ecology's Shade model (Ecology, 2003) was used to estimate shading of Hangman Creek from the Idaho border to the mouth. Shade was calculated at 100-meter intervals along the streams and then averaged over 1000-meter intervals.
- The rTemp model was used to estimate future stream temperatures after full shading is attained upstream and downstream of the Tekoa WWTP so maximum effluent temperature limits could be calculated.

Tributaries were not analyzed directly from aerial photos and GIS tools. The tributaries and perennial streams in the Hangman Creek watershed are narrow enough that riparian vegetation shade would usually dominate stream cooling compared to geographic features. Shade curves and a shade table were created from the Shade model vegetation regional analysis. Shade potential for tributaries can be estimated when channel direction and widths are known.

The water quality standards require the water in Hangman Creek to maintain a 7-day average daily maximum (7DADM) temperature of 17.5°C. If the 7DADM exceeds 17.5°C due to natural conditions, the natural condition temperature becomes the criterion. Cumulative sources to the stream must not increase water temperatures by 0.3ºC. Ecology cannot determine true natural conditions for the watershed because reference conditions, models, and background data that would accurately assess the true natural conditions are lacking.

Instead Ecology uses a condition referred to as the *system potential*. System potential is the estimated water temperature if mature riparian vegetation and microclimate conditions were present along with any local groundwater and any channel or streamflow improvements planned for the future. The modeled shade in the system-potential scenario is based on the direction of the stream compared to the path of the sun and the native vegetation characteristics normally found in an undisturbed riparian area. Hangman Creek system-potential scenario assumed no changes in streamflow, groundwater, or channel conditions. The most appropriate system-potential shade scenario was a combination of willows and pines, 100-feet wide, on both sides of the creek:

- 35 foot width of willow at a 75% density and maximum height of 30 feet
- 65 foot width of pines at a 50% density and maximum height of 80 feet

The Hangman Creek mainstem model results for system-potential shade and the current shade conditions are graphically displayed in Figure ES1. The average difference between current and system-potential shade was 26%, with the greatest need for additional shade in the upper 18 miles of the watershed and along the last six miles near the mouth. Some ecoregional features in the watershed may not allow the recommended riparian widths and vegetation heights. Additional temperature decreases may be possible with channel restoration, sediment controls, and wetland restoration.

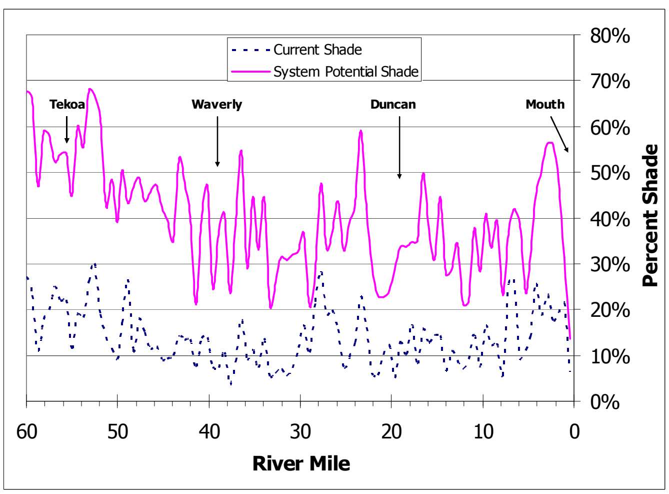

Figure ES1. Current conditions and system-potential shade estimates (1000-meter averages) along Hangman Creek based on the shade model.

Table ES4 provides the amount of increased shading recommended for individual sites along Hangman Creek on the 2004 303(d) list and for the proposed 2006/2008 303(d) list sites. Tributaries are also listed in the table. These were not directly modeled, so they require a different approach. The shade curve (Figure ES2) is based on the system-potential shade used in the Shade model for the mainstem Hangman Creek. As channel measurements and orientation data are gathered at tributary sites, a system shade potential can be compared to existing conditions and a load allocation can be assigned.

Table ES4. Percent of effective shade required to meet heat load allocations.

Reach Location	Shade Required (percent)
Rattler Run Creek at the mouth	Use Shade Curve
Rock Creek at the mouth	Use Shade Curve
California Creek at the mouth	Use Shade Curve
Marshall Creek at the mouth	Use Shade Curve
Hangman Creek at river mile 3.6	45
Hangman Creek above Marshall Creek	32
Hangman Creek at Hangman Valley Golf Course	28
Hangman Creek at river mile 18.2	34
Hangman Creek at Duncan	34
Hangman Creek at Latah Road	42
Hangman Creek at Keevy Road	37
Hangman Creek at Bradshaw Road	21
Hangman Creek at Hays Road	29
Hangman Creek at Roberts Road	40
Hangman Creek at Spring Valley Road	47
Hangman Creek at Fairbanks Road	48
Hangman Creek above Tekoa WWTP	50

Shade Required is the percent of the water surface effectively in shade from the surrounding vegetation.
WWTP is wastewater treatment plant.
Use Shade Curve indicates that the percent effective shade from vegetation is estimated from the shade curved based on the stream's width. The shade curve was developed from Shade model vegetation regional analysis.

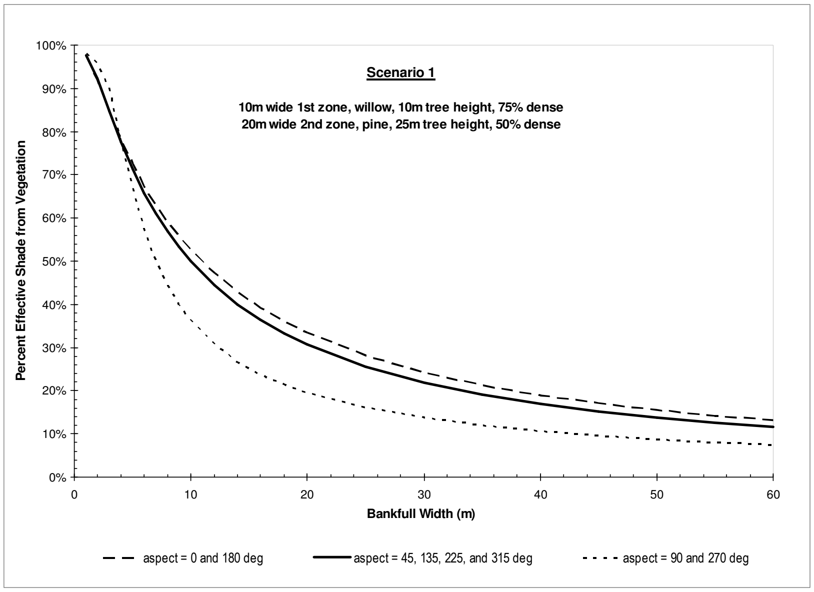

Figure ES2. Shade curves for the Hangman Creek watershed.
A stream with an aspect of 0 or 180 degrees is oriented north and south.

The water quality standards allow an increase of 0.3ºC over natural conditions for all human-caused sources for establishment of the temperature allocations. Point sources also must be regulated to meet the incremental warming restrictions established in the standards to protect cool water periods. This is especially important in the late spring and early fall when stream temperatures may be lower than effluent temperatures but dilution from streamflows is low.

Because water temperatures may exceed 17.5ºC on a 7-day average daily maximum in wastewater receiving water areas of the watershed from late-April through October, all point sources required temperature wasteload allocation evaluations. Unfortunately, few of the six WWTPs have monitored temperature, and nothing is known about stormwater temperatures. However, only two WWTPs discharge during the hottest period of the year when effluent may pose the most serious instream temperature problem. Temperature monitoring will be included in all NPDES permits, and temperature wasteload allocations have been recommended.

As summer Hangman Creek temperatures approach or exceed 17.5°C, the temperature at the edge of any mixing zone equals or exceeds criteria, so any additional warming from effluent would be a violation of criteria. This posed a special problem for establishing effluent temperature limits for Tekoa and Spangle WWTPs since seasonally they lack dilution factors during these periods even when site-potential shade would be present.

Enough water temperature and flow data just upstream of the Tekoa WWTP were available to estimate a set of monthly maximum effluent temperature permit limits. The model rTemp was used with the shade output from the Shade model to predict daily maximum temperatures under Hangman Creek system-potential shade conditions. **Average monthly 7DADM temperatures for June, July, and August were 18.2º C, 21.5º C, and 17.7º C, respectively. The Tekoa WWTP monthly maximum effluent will be limited to these temperatures. The limits are also applied to the Spangle WWTP until local data can be collected. The WLAs for temperature should be identified in a table (such as Table 30) for all the point source dischargers. If they do not discharge during the critical season, then no WLA are needed, of course.**

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Ecology assumes the temperature of water leaving a WWTP with properly constructed wetland treatment is similar to a natural wetland of the same size and flow regime discharging to a stream or creek. Therefore, according to Ecology guidelines (Hicks, 2007), additional heat reduction is not necessary. In the Hangman Creek watershed, three facilities (that usually do not discharge during the summer low-flow critical season) fall into this category:

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- **Fairfield (Rattler Run),**
- **Freeman School District (Little Cottonwood Creek)**
- **Cheney (Minnie Creek)**

Currently, EPA does not agree with Ecology's assumption about natural and constructed wetland systems. If any of these facilities discharge during the critical period (June-August) in the future, they may be required to meet the same limits established for the Tekoa WWTP. If the facility plans to discharge during the critical period in the future, the additional temperature data collected under their new NPDES permits will be used to calculate wasteload allocations.
I have no interest in punishing these small dischargers and appreciate that wetland treatment systems can provide a number of other environmental benefits, besides wastewater treatment. It is just that there is no regulatory discretion of which I am aware to justify not specifying WLAs for discharge of pollutants from a treatment system if there is a potential to cause or contribute to water quality problems. I have a call into my Regional Office to see if they will simply accept Ecology assuming that these discharges represent a natural condition w/o any documentation. I can believe that discharge from a well designed and maintained constructed wetland treatment system could mimic the water quality characteristics of the outflow from a natural wetland. However, I maintain that the TMDL needs to identify WLA for discharges from these dischargers that are protective of receiving water quality were they to discharge during the critical period. Again, no WLAs are necessary if they do not discharge during times when they might affect the quality of the receiving water.

If Rock Creek 7DADM temperatures reach the 17.5ºC criterion in April or May, Rockford WWTP effluent can reach a 7DADM of 18.25 ºC because the facility is only allowed to discharge when a dilution factor of 3.5 is available in Rock Creek. Historically, Rock Creek has had inadequate flows for Rockford WWTP to discharge during the critical period.

All NPDES-permitted discharges in the state are now required to increase the temperature monitoring frequency of their effluents and receiving waters. The monitoring will provide data to ensure the treatment methods of wastewater and stormwater are properly designed to dissipate heat before entering the receiving water. Storm events over seven days during the critical period are unlikely in the Spokane area. So, stormwater temperature effects on Hangman Creek may not occur. If monitoring demonstrates effects on water temperatures, limits and wasteload allocations will need to be revised.

The following conclusions and recommendations are based on this temperature TMDL evaluation:

Conclusions

- Many reaches of Hangman Creek and its tributaries cannot meet the 7-day average daily maximum (7DADM) 17.5ºC temperature criterion during the June-August critical (low-flow) period.
- Groundwater and springs play an important cooling role in the lower 10 miles of Hangman Creek below its confluence with Marshall Creek.
- A buffer of mature riparian vegetation along the banks of the creek and its tributaries is expected to decrease instream average daily maximum temperatures to system-potential levels.
- Site-specific metrics of channel width and aspect will be necessary to apply the shade curve load allocations to tributaries and perennial streams.

Recommendations

- Channel restoration measures, including the restoration of a functioning riparian area, should be implemented throughout the watershed to reduce heat loads on the stream.
- Monthly WWTP effluent 7DADM temperatures for facilities in Tekoa and Spangle are based on receiving water temperatures in June-August under system-potential shade conditions. Additional temperature monitoring data required in NPDES permits will allow refinement of these 7DADM effluent limits.
- Cheney, Fairfield, and Freeman School District wetland treatment system effluents do not ~~usually~~ discharge when instream receiving water temperatures are greater than 17.5 ºC. WLA similar to those established for Tekoa and Spangle will be assigned as permit limitations if discharges from these facilities are determined to occur during the critical period. ~~Ecology NPDES permit guidance expects wetland system temperatures to function as natural systems.~~ **~~Ecology will continue discussions with EPA to determine if additional limits are required if critical discharges to receiving waters occur in the future. Monitoring will be required at that time.~~ This issue should be resolved before the TMDL is submitted, preferably before going out to public review.**

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- The Rockford WWTP does not discharge effluent during critical temperature months, but additional temperature monitoring will be required under Ecology policies. **Some effluent temperature limits may be necessary during low streamflow and elevated temperature**

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conditions in April and May. **I recommend specifying what WLAs might be if discharges during April/May need to be regulated to protect water quality. Idea: Flow or temperature-based effluent limitations have been established in other TMDLs (see Chehalis River as an example, (an oldie and not the best))**

- All WWTP facilities should comply with Ecology's Water Quality Program policy requiring receiving water, effluent temperatures, and discharge volumes monitoring during spring through fall. These data will help us to understand thermal and dilution cycles so that compliance schedules and operational/facility options can be designed.
- Watershed managers will need to ensure streamside shading and other heat reduction measures are conducted in coordination with WWTP facilities. Effluent temperature allocations will become better defined as stream temperatures are lowered to their system potentials.
- Spokane County, the City of Spokane, and Washington State Department of Transportation Phase 2 municipal stormwater thermal effects are not expected to impact Hangman Creek because 7-day storm events are unlikely during the June-August critical period. But, permit holders should evaluate their systems and prevent stormwater heating of Hangman Creek, especially during the late spring and early fall.

Turbidity and Total Suspended Solids

Turbidity and suspended solids have been longstanding problems in Hangman Creek. In 1980 and in 1988, Hangman Creek Water Quality Index scores were among the worst in the state for turbidity and suspended solids (Singleton and Joy, 1981; Hallock, 1988). Naturally eroding streambanks and upland soils in various parts of the watershed have been further destabilized by poor road-building practices and some agricultural practices. The sediment and associated turbidity degrade aquatic habitats and transport excessive amounts of nutrients in Hangman Creek and the Spokane River.

According to Ecology monthly monitoring data at the mouth of Hangman Creek, total suspended solids (TSS) concentrations and turbidity have decreased over the past 10 years. This decrease is partially due to lower than normal discharge volumes, but it can also be attributed to efforts to improve the stream channel, restore riparian areas, and a switch to less erosion-prone farming practices.

However, recent fish and benthic macroinvertebrate sampling results indicate most of the watershed has a poor aquatic community structure that is partly the result of sediment impacts (SCCD, 1998; Peters, Kinkead, and Stanger, 2003; McLellan, 2005; Lee, 2005; Ecology, 2005). Each year Hangman Creek aquatic life communities are subject to several intense turbidity events of extended duration that have negative habitat, behavioral, and health effects on the aquatic life. Sediment transport from Hangman Creek to the Spokane River is also a great concern to water quality management of Lake Spokane and the operation of several dams along the Spokane River.

Turbidity is regulated under Washington State water quality standards with specific criteria; suspended sediments are not. Turbidity loads cannot be calculated since turbidity is a measure of visibility through water, not a concentration of something in the water. However, the turbidity listings in this watershed call attention to the serious problem of erosion and excessive sediment transport in these streams. The designated use of "salmonids spawning, rearing, and migration" is impaired by elevated suspended sediment and could have also been listed on the 303(d) list under the water quality standards narrative criteria. Therefore, this TMDL will set allocations for TSS to address the impairment of the narrative criteria.

Several tools were used to examine the suspended sediment and turbidity data from the Hangman Creek watershed to evaluate different parts of the problem. Statistical tests were run to compare sediment and turbidity values. A multiple regression analyses method by Cohn (1988) was used to simulate the seasonal pattern of suspended sediment loading at the mouth of Hangman Creek over a 14-year period. The WARMF model was developed to see where sediment loads were coming from and how they were transported through the watershed.

EPA, Coeur d'Alene Tribe, Ecology, and SCCD agreed that an assessment of the whole watershed was necessary to evaluate the sources, transport, and relationship between TSS loads and watershed landscape, land uses, and hydrology. CDM (2007) divided the watershed into 36 catchments in the WARMF model to characterize hydrology and sediment delivery (Figure ES4). Local soils, land uses, climate, and geographic features of the land and stream channels were generalized within each of the 36 catchments of the WARMF model. The average size of the catchments was 12,000 acres with a range of 576 acres to 27,785 acres. Model results were calculated daily based on rainfall, temperature, and point source inputs.

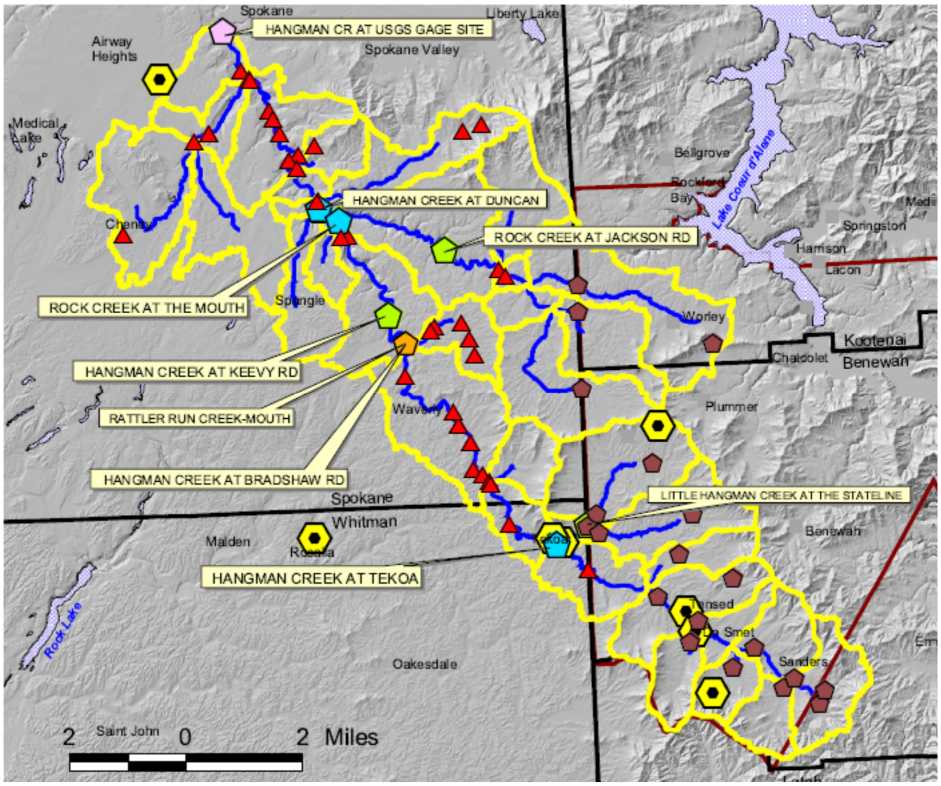

Figure ES4. Delineated catchments and stream layout for the Hangman Creek watershed Analysis Risk Management Framework (WARMF) model (Cadmus Group and CDM, 2007).

The model analysis estimated the current suspended sediment/TSS loads and reductions that could be expected after a progressive set of BMPs were in place. The reductions were estimated for the mouth of Hangman Creek, 303(d) sites, and other critical tributary sites in the watershed. The characteristics of an estimated full protection scenario are used to determine necessary reductions of total suspended solids. The following actions were identified by the Advisory Committee as the scenario that would result in full protection of the designated uses:

- Convert 60% of the agriculture in the watershed to direct seed or conservation practices.
- Reduce the streambank erosion in the upper watershed (above Fairfield) by 50%, and high-bank erosion in the lower watershed from Lake Missoula flood sediments by 10%.
- Increase forest cover in catchments above Rockford and Tensed by 50%.
- Limit residential growth to levels below 10% in the lower watershed (catchments 3, 4, 7, 9 and 10).

- Have riparian buffers established all along the mainstem channels and tributaries.

The annual suspended sediment loads at the mouth of Hangman Creek under the estimated full protection scenario are 20% to 30% lower than the simulated current condition (Table ES5). The annual variability is induced both by the intensity and frequency of runoff events and the location of those events within the watershed. Years with higher annual flows will also naturally generate more streambank erosion from the high streambanks along the lower reaches of Hangman Creek that are not easily remedied even under the estimated full protection scenario actions.

Table ES5. Suspended sediment reduction predicted from WARMF model scenario estimates for annual suspended sediment loading from Hangman Creek to the Spokane River. WARMF model current and estimated full protection scenario condition results were compared.

Water Year	Multiple Regression Model (tons/year)	Estimated Reduction	Estimated Load Capacity (tons/year)
1999	188,252	22%	147,206
2000	90,677	25%	67,872
2001	1,604	31%	1,109
2002	73,770	28%	53,326
2003	16,503	21%	13,101
2004	30,605	32%	20,846
2005	2,832	29%	2,022

The WARMF model suggested major sediment erosion generated from the same sources that have been discussed in previous reports for the watershed (SCCD, 1999; 2002; 2005a; 2005b). Conventional agricultural practices and streambank erosion are the largest sediment sources in most areas of the watershed. Table ES6 summarizes the overall estimated suspended sediment reduction for the 303(d) listed areas if the estimated full-protection activities are implemented.

Table ES6. WARMF model simulation results for overall suspended sediment reductions and source reductions estimated at 303(d) sites in the Hangman Creek watershed.

Site	Overall Reduction	Primary Sources	Reduction to Sources
Hangman Creek at Bradshaw Road	19%	Conventional Agriculture	56%
		Streambanks	74%
		Rangelands	31%
Little Hangman Creek	15%	Conventional Agriculture	55%
Rattler Run Creek	15%	Conventional Agriculture	54%
Rock Creek at Jackson Road	17%	Conventional Agriculture	55%
		Rangelands	18%
		Streambanks	90%

The results of the estimated full protection scenario were used to estimate the daily suspended solids concentration at the mouth of Hangman Creek. The severity of impacts to various fish populations from suspended sediment scores were calculated from a formula developed by Newcombe and Jensen (1996). Estimated full protection scenario TSS events were compared to the current conditions (Figure ES5). Significant improvements were predicted for the number, intensity, and duration of the events. The BMPs throughout the watershed were successful in either lowering or shortening the duration of the highest lethal and sub-lethal conditions scores. Lethal and sub-lethal conditions in late spring and summer and in the early fall were eliminated. These are the critical spawning and emergence periods for fully protecting and enhancing redband and other trout populations.

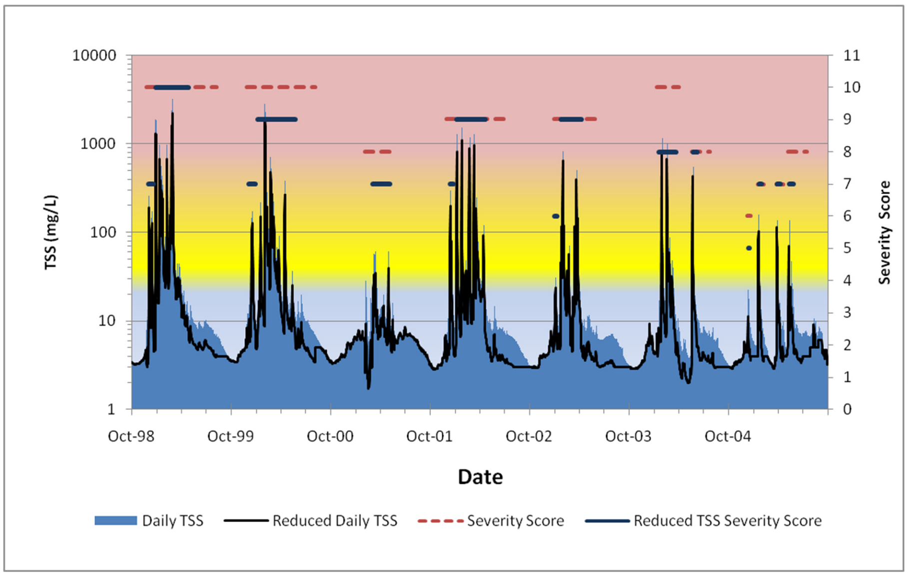

Figure ES5. A comparison of estimated current and estimated full protection (reduced) scenario suspended sediment conditions for trout species at the mouth of Hangman Creek including lethal and sub-lethal severity scores calculated from the formula by Newcombe and Jensen (1996).

Data for tributary and upstream reach areas are not available to do a similar analysis. But TSS reductions estimated by the WARMF model (Table ES6) are expected to yield similar improvements. Aquatic communities should improve as the duration and intensity of TSS events are decreased from implementing BMPs. Sediment rating curves should be developed for key sites to monitor changes.

The differences between the current and estimated full protection scenario results provide the suspended sediment targets for six sub-watersheds of Hangman Creek. Table ES7 summarizes the relative distribution and the overall suspended sediment reduction for the various sub-watersheds. Future load analyses will need to consider the large amount of sediment stored within the watershed channels and how the transport rate of that sediment to the mouth of Hangman Creek or its major tributaries varies from year to year.

Table ES7. Estimated distribution of sources generating suspended sediment in sub-watersheds of Hangman Creek under current condition WARMF model scenarios and estimated source reduction expected with implementation of estimated full protection scenario actions.

Sub-Watershed	Current percent of sources	Estimated source reduction	Land Area percent of watershed
Upper Hangman Creek	35%	26%	20%
Little Hangman Creek and Hangman Creek from Tekoa to Bradshaw	26%	16%	19%
Hangman Creek from Bradshaw to Duncan and Rattler Run	1%	15%	8%
Rock Creek	20%	18%	27%
Marshall Creek	2%	8%	11%
Lower Hangman Creek	16%	11%	15%

The most obvious example of the problem of sediment transport rates is cross-border loading. Approximately 35% of the Hangman Creek watershed lies in catchments of Rock Creek, Little Hangman Creek, and upper Hangman Creek in the Coeur d'Alene Indian Reservation and in Idaho. Up to 60% of the water is delivered from these catchments annually.

A cooperative strategy between jurisdictions yields a more comprehensive approach to controlling suspended sediment and turbidity sources in the watershed. However, Washington State cannot dictate to the Coeur d'Alene Tribe and Idaho what measures they need to take in Hangman Creek, or how to allocate suspended sediment loads in their jurisdictions. The Idaho Department of Environmental Quality (IDEQ) has completed a TMDL for the upper watershed (approximately 10,000 acres) that set locations and reductions for sediment. The Coeur d'Alene Tribe has collected data for the development of a TMDL for their reservation. The Tribe has participated in the development of Washington TMDLs and concurs with the assumptions used in the modeling (personal communication with Scott Fields, email 1/16/09).

The load allocations for both the sub-basin geographic areas and the 303(d) listed segments are summarized in Table ES8. The sub-basin load allocations are estimates of the reductions from the entire land area that are necessary to meet the load allocation at the 303(d) listed stream segment.

Table ES 8. Total suspended solids load allocations for geographic sub-basins and 303(d) listed stream segments.

	Sub-basin	303(d) listed segment	Estimated % reduction	
			Basin	303(d)
Hangman Creek	Upper Hangman Creek	Hangman Creek at Bradshaw Road (ID 40942)	26%	19%
	Hangman Creek from Tekoa to Bradshaw Rd		16%	
	Hangman Creek from Bradshaw Rd to Duncan		15%	n/a
	Lower Hangman Creek		11%	
Tributaries	Little Hangman Creek	Little Hangman Creek (ID 40940)	16%	15%
	Rattler Run Creek	Rattler Run Creek (ID 40941)	15%	15%
	Rock Creek	Rock Creek at Jackson Road (40943)	18%	17%
	Marshall Creek		8%	n/a

n/a – there are no 303(d) listed segments in this geographic area.

The current TSS NPDES permit limits for the six municipal WWTPs in the Washington portion of the watershed are adequate for TSS control in the watershed. The combined WWTP loads are insignificant compared to the event-based loads driving field and streambank erosion.

Stormwater in areas under Phase 2 and construction permits will need to be adequately managed to reduce TSS loads to lower Hangman Creek and its tributaries. BMPs for TSS in municipal stormwater are well-known and effective in reducing 80% of TSS in runoff. Therefore, if the jurisdictions are in compliance with the Stormwater Phase II NPDES permit, they will be in compliance with TSS wasteload allocations under this TMDL. The estimated full protection scenario limited increased residential land use to less than 10% over current conditions. If residential land use exceeds the estimated full protection scenario, wasteload allocations may need to be reevaluated.

Wasteload allocations for all point sources are shown in Table ES9.

Table ES9. Total suspended solids wasteload allocations for the Hangman Creek watershed.

Source	Permit Requirements		WLA
	Average Monthly Limit	Average Weekly Limit	
Tekoa WWTP	30 mg/L, 34.5 lbs/day	45 mg/L, 51.7 lbs/day	same
Fairfield WWTP	15 mg/L, 29.0 lbs/day	23 mg/L, 44.5 lbs/day	same
Spangle WWTP	15 mg/L, 8.5 lbs/day	23 mg/L, 12.8 lbs/day	same
Rockford WWTP	30 mg/L	45 mg/L	same
Freeman School District #358	20 mg/L, 7.2 lbs/day	30 mg/L, 10.8 lbs/day	same
Cheney WWTP	15 mg/L, 338 lbs/day	23 mg/L, 507 lbs/day	same
Industrial Facility Stormwater[1]	27 mg/L	88 mg/L[2]	same
Spokane County Stormwater	All known and reasonable treatment		80% reduction[3]
City of Spokane Stormwater	All known and reasonable treatment		80% reduction[3]
Washington Department of Transportation Stormwater	All known and reasonable treatment		80% reduction[3]
Construction Site Stormwater[4]	All necessary best management practices Turbidity Benchmark: 25NTU Background and discharge sampling required Turbidity Limit: 5 NTU over background or when background is over 50 NTU less than a 10% increase over background		same

[1]No permitted industrial facilities currently exist in the watershed.
[2] Limit is a maximum daily (not average weekly).
[3]Best management practices estimate 80% removal of TSS from stormwater sources (Ecology, 2004).
[4] Construction stormwater NPDES permit regulates turbidity but does not regulate TSS.

Conclusions

- Significant cross-border TSS loads will require close cooperation with the Coeur d'Alene Tribe and Idaho to establish erosion reduction measures and improve Hangman Creek, Little Hangman Creek, and Rock Creek.
- Turbidity and suspended sediments have been longstanding problems in Hangman Creek. Naturally erosive streambanks and erosive upland soils in various parts of the watershed have been further destabilized by poor road building and agricultural practices.
- The duration and intensity of suspended sediments events have lethal or sub-lethal effects on native redband trout and other fish populations in the watershed. Events during the mid-to-late spring through the fall periods are especially damaging to aquatic communities.

- The sediment and associated turbidity have not only degraded aquatic life and habitats, but they have transported excessive amounts of sediment, nutrients, and other contaminants within Hangman Creek and to the Spokane River.
- Elevated suspended sediments and turbidity have been most pronounced in January through May, especially when conventionally tilled fields are susceptible to erosion by rains falling on partially frozen and snow-covered soils with little residue and high water erodes streambanks (SCCD, 2002).
- For this TMDL, reductions of TSS loads are an adequate surrogate for the turbidity 303(d) listings in the watershed.
- The estimated full protection scenario and associated load reductions will reduce the number, intensity and duration of TSS events. This will reduce the number of lethal and sub-lethal impacts on trout and other fish, especially during the most sensitive life-stages in the mid-to-late-spring through fall. Successful implementation of these measures will provide full protection for these sensitive life-stages and improve the fish communities in the watershed.

Recommendations

- Aquatic communities and suspended sediment loads should continue to be monitored to establish baselines and to measure success with erosion control and other improvements. Sediment rating curves should be established for key sites in the watershed.
- An estimated 20% to 30% in annual TSS loads to the Spokane River will be reduced if estimated full protection actions are implemented. Sediment loads in 303(d) listed areas of the watershed will be reduced by a long-term annual average of 15% to 19%.
- Conversions of conventional agricultural practices to conservation practices is needed to meet the load allocations in this TMDL as this action will have the biggest impact in reducing TSS in the watershed.
- Streambank erosion control is necessary to decrease sediment generation and transport especially in the reaches between Fairfield and Tekoa.
- Municipal and construction stormwater discharges are potential sources of TSS during storm events. Spokane County, City of Spokane, and Washington State Department of Transportation have coverage under the state municipal stormwater permits in the residential growth areas in the lower reaches of Hangman Creek and Marshall Creek. Common stormwater BMPs should prevent an estimated 80% of the stormwater TSS load from reaching Hangman Creek.
- WWTPs are insignificant sources of turbidity and solids in Hangman Creek compared to event-based erosion. Current municipal NPDES permits limit TSS to loads far lower than are of concern in the watershed, and permit limits will be adequate as wasteload allocations.
- WARMF or a similar model should be supported with better local data for calibration and scenario-building.

Implementation Strategy

This *Implementation Strategy* (1) describes the roles and authorities of cleanup partners and programs and (2) provides a strategy to achieve the water quality standards for fecal coliform bacteria, total suspended solids/turbidity, and temperature. Because of regional interest in reducing Hangman Creek's phosphorus contribution to the Spokane River, this *Implementation Strategy* also includes strategies to reduce nutrients. The development of this plan was a collaborative effort by a diverse group of interests in the watershed.

Implementation activities will generally involve the Spokane County Conservation District (SCCD), Washington State Department of Ecology (Ecology), Spokane County, the City of Spokane, the six WWTPs, the Coeur d'Alene Tribe, and the U.S. Environmental Protection Agency (EPA). Implementation will be jointly facilitated and tracked by the SCCD and Ecology. These agencies will also involve other agencies and groups, such as the Spokane Regional Health District, the Direct Seed association, Washington State University Extension, seed and fertilizer companies, local producer-based cooperatives, the Natural Resources Conservation Service (NRCS), and the Farm Service Agency. To effectively reduce nonpoint source pollution, these agencies will need to seek cooperation with private landowners to implement BMPs designed to address the pollution issues.

After the EPA approves this TMDL, interested and responsible parties will work together to develop a *Water Quality Implementation Plan*. The plan will describe and prioritize specific actions planned to improve water quality and achieve water quality standards.

The six WWTPs and the three stormwater jurisdictions covered by stormwater permits were assigned wasteload allocations in this TMDL to ensure they do not contribute to water quality standards violations. These wasteload allocations will be implemented through their National Pollutant Discharge Elimination System (NPDES) permits. Ecology recognizes the difficultly of achieving some of the wasteload allocations established in this document and will work collaboratively with the dischargers to develop a comprehensive strategy to protect water quality.

A Hangman Creek Advisory Committee was formed in April 2004. In addition to the point sources in the watershed, the committee identified 11 water quality nonpoint issues that were potential sources of the water quality problems in the watershed:

1. Sediment/nutrients from agricultural operations.
2. Sediment/fecal coliform from livestock and wildlife.
3. Nutrients/chemicals from residential uses.
4. Sediment/nutrients from agricultural field ditches.
5. Nutrients/fecal coliform from improper functioning septic systems.
6. Sediment from gravel and summer roads.
7. Sediment from sheer or undercut banks.
8. Sediment/fecal coliform from stormwater.
9. Sediment from poor forestry management.
10. Sediment from roadside ditching.
11. Solar heating from lack of riparian shade.

To address the nonpoint sources, the advisory committee developed a list of BMPs to address each of the nonpoint source water quality issues identified. Stormwater is included because much of the watershed is not covered under a stormwater permit. Many of the BMPs address more than one of the water quality issues. To address the water quality parameters in this TMDL, pollution reductions will be accomplished through BMPs that:

- Reduce erosion.
- Reduce runoff carrying sediment.
- Reduce livestock impacts.
- Increase shading of streams.
- Inform and educate watershed residents about water quality issues.

Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this water improvement plan are met. There are many sources of funding and technical assistance to facilitate implementing this TMDL.

Once EPA approves the TMDL, a *Water Quality Implementation Plan* (WQIP) must be developed within one year. Ecology and the SCCD will work with local people to create this plan, choosing the combination of possible solutions they think will be most effective in their watershed. Elements of this plan include:

- Who will commit to do what.
- How to determine if the implementation plan works.
- What to do if the implementation plan doesn't work.
- Potential funding sources.

In developing the WQIP, Ecology and the SCCD will ensure the plan addresses the recommendations made in this report.

What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, each state is required to have water quality standards designed to protect, restore, and preserve water quality. Water quality standards are set to protect designated uses such as cold water biota and drinking water supply.

Every two years, states are required to prepare a list of waterbodies--lakes, rivers, streams, or marine waters--that do not meet water quality standards. This list is called the 303(d) list. To develop the list, Ecology compiles its own water quality data along with data submitted by local state and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

TMDL process overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. A TMDL is the highest amount of a pollutant a surface waterbody can receive and still meet water quality standards. The difference between the TMDL and the current amount of pollutant coming from point (discrete) and nonpoint (diffuse) sources is how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, local governments, agencies, and the community develop a strategy to control the pollution, and a monitoring plan to assess effectiveness of the water quality improvement activities.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a point source such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a set of nonpoint sources such as general urban, residential, or farm runoff, the cumulative share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Water quality assessment / Categories 1-5

The Water Quality Assessment categorizes waterbodies based on water quality data. This assessment gives an indication of the condition of Washington's water. The 303(d) list is one of the categories within the assessment. The five categories are:

- Category 1 – Meets standards for parameter(s) for which it has been tested.
- Category 2 – Waters of concern.
- Category 3 – Waters with no data available.
- Category 4 – Polluted waters that do not require a TMDL because:
  - 4a – Has an approved TMDL and it is being implemented.
  - 4b – Has a pollution control plan in place that should solve the problem.
  - 4c – Impaired by a non-pollutant such as low water flow, dams, culverts.
- Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Total Maximum Daily Load analyses: Loading capacity

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. EPA defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Why is Ecology Conducting a TMDL Study in this Watershed?

Overview

Ecology and the Spokane County Conservation District (SCCD) are conducting a TMDL study because Hangman Creek was identified on the 1998 303(d) list of impaired waters for not meeting Washington State water quality standards for fecal coliform, dissolved oxygen, pH, and temperature. Hangman Creek and several of its tributaries (Little Hangman Creek, Rattler Run Creek, and Rock Creek) were also included on the 2004 303(d) list of impaired water for not achieving state water quality standards for fecal coliform, dissolved oxygen, turbidity, and temperature.

Recent monitoring by the SCCD and Ecology has identified several other water quality problems not included on either list of impaired waters: sediment load, low flows, and total phosphorus. Streams are not listed on the 303(d) list for these parameters because the water quality standards do not set criteria for them.

Issues such as storm-water runoff, sedimentation, riparian vegetation losses, streambank erosion, wetland losses, and agricultural and forestry management are major concerns for the watershed.

Study area

Hangman Creek (also known as Latah Creek) is a trans-boundary watershed that begins in the foothills of the Rocky Mountains of northern Idaho, extends over the southeastern portion of Spokane County, Washington (Figure 1), and is a tributary to the Spokane River. It encompasses over 689 square miles (approximately 441,000 acres). The watershed is dominated by dryland farming, but like other eastern Washington watersheds, is experiencing increases in urbanization and changes in land use practices.

The TMDL evaluation is limited to the 446 square miles of watershed within Washington, although landscape modeling was conducted on the entire watershed. Rock Creek and Little Hangman Creek trans-boundary watersheds within Washington are included in this evaluation. The Coeur d'Alene Tribe is conducting a TMDL study and the State of Idaho has completed a TMDL for the portions of the watershed within their jurisdictions.

Pollutants addressed by this TMDL

This TMDL study addresses fecal coliform bacteria, temperature, and turbidity listings in the Washington portion of the Hangman Creek watershed.

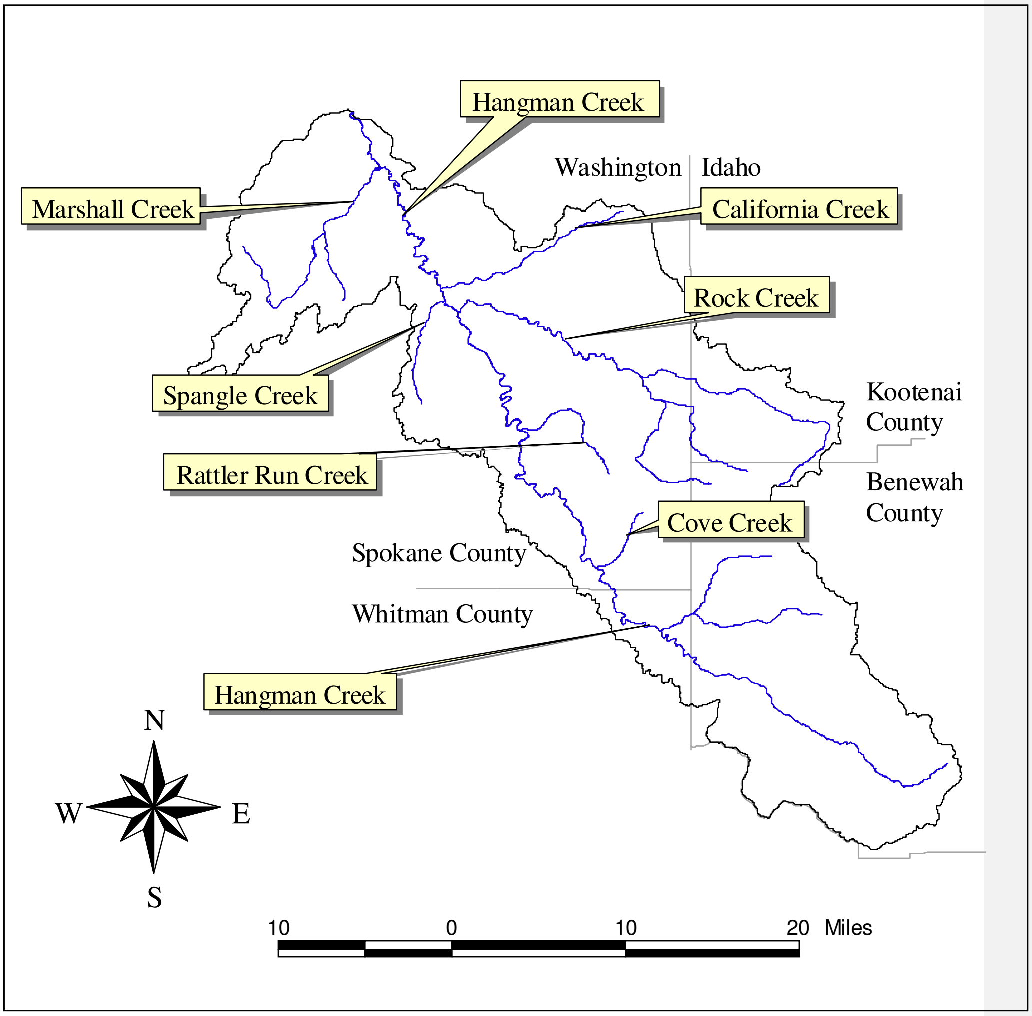

Figure 1. Hangman Creek watershed near Spokane, Washington (SCCD, 2005a).

Impaired beneficial uses and waterbodies on Ecology's 303(d) list of impaired waters

The main beneficial uses to be protected by this TMDL are recreation and aquatic habitat. The specific waterbodies, parameters, listing ID, and locations from Ecology's 2004 303(d) list are in Table 1. The work performed for this TMDL evaluation also identified additional waterbodies that qualify for the proposed 2006/2008 303(d) list (Table 2). Both sets of lists will be addressed and receive allocations in this TMDL report.

Table 1. Study area 303(d) listings (2004 list) addressed in this report.

Waterbody	Parameter	Listing ID	Section, Township, Range
Hangman Creek	Fecal Coliform	16862	Section 23 T25N R42E
Hangman Creek	Fecal Coliform	16863	Section 16 T22N R44E
Hangman Creek	Fecal Coliform	6726	Section 13 T20N R45E
Hangman Creek	Fecal Coliform	41992	Section 25 T20N R46E
Hangman Creek	Turbidity	40942	Section 16 T22N R44E
Little Hangman Creek	Fecal Coliform	41994	Section 24 T20N R45E
Little Hangman Creek	Turbidity	40940	Section 13 T20N R45E
Rattler Run Creek	Turbidity	40941	Section 16 T22N R44E
Rock Creek	Fecal Coliform	41996	Section 23 T23N R44E
Hangman Creek	Temperature	3736	Section 23 T25N R42E
Rock Creek	Turbidity	40943	Section 23 T23N R44E

This watershed has other water quality issues that will not be addressed in this TMDL. In particular, the parameters listed in Table 3 occur in the study area, but are not addressed in this report. Un-ionized ammonia concentrations were incorrectly calculated for the 2004 list; therefore, the data from these sites do not exhibit ammonia toxicity above aquatic life criteria. Ammonia listings in Table 3 on the 2004 303(d) list, but are probably listed in error. Suggestion follows: This water quality evaluation also documented that streams throughout the watershed are severely degraded by excessive amounts of sediment loading. Washington does not currently have water quality criteria for sediment and there are no 303(d) listing for sediment-related impairment except for the limited turbidity listings. Beneficial uses for these waters are designated in the narrative portion of the water quality standards and these uses are impaired by the current amount of sediment entering the streams within the watershed.

In addition, a phosphorus load allocation will be recommended for Hangman Creek by the *Spokane River/Lake Spokane Dissolved Oxygen TMDL* study. The Spokane River and Lake Spokane exhibit depressed dissolved oxygen (DO) levels during low flow in the summer months. Phosphorus loads from Hangman Creek may contribute to algae growth in the lake that eventually depress oxygen levels. Phosphorus may also have a role in the DO and pH listings in the Hangman Creek watershed.

At the time of this study, resources were not available to address the Hangman Creek DO and pH listings and investigate the interaction between nutrients, pH and DO. However, Ecology is seeking opportunities to complete a DO and pH TMDL which will likely address nutrients by 2010. Meanwhile, the implementation activities outlined in this TMDL will benefit dissolved oxygen, pH, and phosphorus in the watershed.

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Table 2. Additional impairments on the proposed 2006/2008 303(d) list which will receive allocations in this TMDL. Most of these listings resulted from data collected for this study.

Waterbody	Parameter	Listing ID	Section, Township, Range
Hangman Creek	Fecal Coliform	45242	Section 01 T21N R44E
Hangman Creek	Fecal Coliform	45250	Section 13 T23N R43E
Hangman Creek	Fecal Coliform	45268	Section 08 T22N R44E
Rattler Run Creek	Fecal Coliform	45310	Section 16 T22N R44E
Rock Creek	Fecal Coliform	45312	Section 12 T23N R43E
Unnamed Creek	Fecal Coliform	45553	Section 13 T21N R44E
Cove Creek	Fecal Coliform	45629	Section 30 T21N R45E
California Creek	Fecal Coliform	46287	Section 18 T24N R45E
Rock Creek	Fecal Coliform	46317	Section 33 T23N R45E
Hangman Creek	Fecal Coliform	46493	Section 30 T21N R45E
Hangman Creek	Fecal Coliform	46497	Section 09 T20N R45E
Rattler Run	Temperature	48303	Section 16 T22N R44E
Rock Creek	Temperature	48333	Section 12 T23N R43E
California Creek	Temperature	48340	Section 03 T23N R43E
Marshall Creek	Temperature	48368	Section 31 T25N R43E
Hangman Creek	Temperature	48370	Section 36 T25N R42E
Hangman Creek	Temperature	48371	Section 31 T25N R43E
Hangman Creek	Temperature	48372	Section 28 T24N R43E
Hangman Creek	Temperature	48373	Section 33 T24N R43E
Hangman Creek	Temperature	48374	Section 11 T23N R43E
Hangman Creek	Temperature	48375	Section 13 T23N R43E
Hangman Creek	Temperature	48376	Section 08 T22N R44E
Hangman Creek	Temperature	48377	Section 16 T22N R44E
Hangman Creek	Temperature	48378	Section 28 T22N R44E
Hangman Creek	Temperature	48379	Section 01 T21N R44E
Hangman Creek	Temperature	48380	Section 30 T21N R45E
Hangman Creek	Temperature	48381	Section 09 T20N R45E
Hangman Creek	Temperature	48382	Section 24 T20N R45E

Table 3. Additional 303(d) listings not addressed by this report.

Waterbody	Parameter	Listing ID	Section, Township, Range
Hangman Creek	Dissolved Oxygen	41985	Section 29 T20N R46E
Hangman Creek	Dissolved Oxygen	41987	Section 16 T22N R44E
Hangman Creek	pH	11391	Section 23 T25N R42E
Rock Creek	Dissolved Oxygen	41990	Section 23 T23N R44E
Hangman Creek	Ammonia*	41977	Section 29 T20N R46E
Hangman Creek	Ammonia*	41978	Section 16 T22N R44E
Little Hangman Creek	Ammonia*	41979	Section 24 T20N R45E

* Preliminary review of the data suggests the ammonia criteria were not applied correctly; therefore, these listings should be dropped from the list.

Why are we doing this TMDL now?

Ecology examines each watershed every five years to determine if there are impaired streams which need a TMDL to restore water quality. In 2003, Ecology considered impaired streams in the Hangman Creek, Little Spokane River, Middle Spokane, and Lower Spokane watersheds.

Water Quality Standards and Beneficial Uses

The Washington State Water Quality Standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). The state Department of Ecology (Ecology) has the authority to adopt rules, regulations, and standards necessary to protect the environment. The EPA Regional Administrator under Section 303(c) (3) of the federal Clean Water Act approves the state water quality standards adopted by Ecology. By adopting these standards, Washington lists characteristic uses to be protected and the criteria used to protect them (WAC 173-201A).

Hangman Creek and its tributaries have not been given any specific use designations in the water quality standards. So they have been given the default water quality standards. The standards include the following general use designation for such waters:

173-201A-600. Use designations — Fresh waters.

(1) All surface waters of the state not named in Table 602 are to be protected for the designated uses of: Salmonid spawning rearing, and migration; primary contact recreation; domestic, industrial, and agricultural water supply; stock watering; wildlife habitat; harvesting; commerce and navigation; boating; and aesthetic values.

Some water quality problems are a result of natural conditions, or do not have specific state or federal criteria and standards. In this TMDL, these include temperature and totals suspended solids (a surrogate parameter for turbidity). The following portions of the water quality standards apply to these water quality problems requiring natural condition assessment or lacking specific criteria:

173-201A-260. Natural conditions and other water quality criteria and applications.

(1) **Natural and irreversible human conditions**

(a) It is recognized that portions of many water bodies cannot meet the assigned criteria due to the natural conditions of the water body. When a water body does not meet its assigned criteria due to natural climatic or landscape attributes, the natural conditions constitute the water quality criteria.

(b) When a water body does not meet its assigned criteria due to human structural changes that cannot be effectively remedied (as determined consistent with the federal regulations at 40 CFR 131.10), then alternative estimates of the attainable water quality conditions, plus any further allowances for human effects specified in this chapter for when natural conditions exceed the criteria, may be used to establish an alternative criteria for the water body…

(2) **Toxic and aesthetics criteria**

(a) Toxic, radioactive, or deleterious material concentrations must be below those which have potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health…

(b) Aesthetic values must not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste…

173-201A-310. Tier I – Protection and maintenance of existing and designated uses.

(1) Existing and designated uses must be maintained and protected. No degradation may be allowed that would interfere with, or become injurious to, existing or designated uses, except as provided in this chapter.

(2) For waters that do not meet assigned criteria, or protect existing or designated uses, the department will take appropriate and definitive steps to bring the water quality back into compliance with the water quality standards.

(3) Whenever the natural conditions of a water body are of lower quality than the assigned criteria, the natural condition constitutes the water quality criteria. Where water quality criteria are not met because of natural conditions, human actions are not allowed to further lower the water quality, except where explicitly allowed in this chapter.

Recreational contact uses

Neither Hangman Creek nor its tributaries in Washington have designated swimming areas, but swimming has been observed by SCCD field personnel at several locations near bridge crossings (for example at Hangman Creek at Duncan Road). Swimming is a listed amenity by the City of Spokane at High Bridge Park at the mouth of Hangman Creek. Canoeing, kayaking, fishing, and wading are seasonal activities in the Hangman Creek watershed. Several kayaking websites describe water quality challenges kayakers face in Hangman Creek.

Fecal Coliform Bacteria

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In the Washington State water quality standards, fecal coliform (FC) is used as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). FC in water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

Coliform bacteria have been used as indicators of fecal contamination since the 1880s (Geldrich, 1966). Coliforms are a group of bacteria with certain shapes that produce gas from sugars and respond to other tests in specific ways. Different sub-sets of the coliform group are used as indicators for specific regulatory purposes. Figure 2 illustrates how the sub-sets within the coliform group are related.

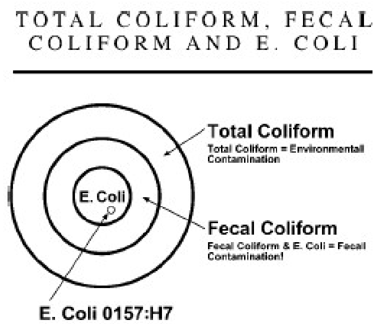

Figure 2. Relationship between total coliform, fecal coliform, and E. coli (Washington State Department of Health, 2005).

Total coliforms are used as indicators of general environmental contamination, and as a regulatory indicator for reclaimed wastewater disposal. For example, the seven-day median concentration of total coliforms cannot exceed 2.2 per 100 milliliters in Class A reclaimed water for use on crops (Washington State Department of Health, 1997).

FC bacteria are used as indicators of the presence of other pathogenic enteric organisms. When FC are found in large numbers, it means that fecal wastes are entering waterways and creating a greater potential for infection from pathogens when people come in contact with these waters. State water quality standards do not distinguish between human and other sources of FC since disease organisms that affect humans are carried in fecal wastes from other warm-blooded animals as well.

Bacteria from the genera *Escherichia, Citrobacter, Klebsiella, Enterobacter*, and *Serratia* (among others) are detected in the FC analysis (APHA et al., 1998). All are present in the feces of warm-blooded animals, but some species may be from other sources as well. Usually, *Escherichia coli* (E. coli) are the dominant species detected in the FC test. Samples with a large number of E. coli would more likely come from a warm-blooded animal source than samples with a high percentage of thermo-tolerant *Klebsiella* species that can be found in pulp waste or rotting vegetation.

The Primary Contact use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category:

"*Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/ 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].*

Compliance is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a waterbody will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for FC are based on allowing no more than the pre-determined risk of illness to humans that work or recreate in a waterbody. The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of FC in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring FC concentrations back into compliance with the standard.

If natural levels of FC (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, warm-blooded animals (particularly those that are managed by humans and thus exposed to human derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

Aquatic life uses

Hangman Creek has no specific aquatic use designations, so the assigned aquatic life criteria are required to protect salmonid spawning, rearing, and migration (WAC 173-201A-600(1)) as stated earlier. These criteria are appropriate considering the Hardin-Davis, Inc. (2003) report provided the following summary of historical and current fish stocks in Hangman (Latah) Creek:

"Historically, Latah Creek [Hangman] *supported salmon and steelhead runs in the mainstem all the way to the headwaters. Anadromous fish were blocked by the construction of Little Falls Dam in 1910. Resident trout still occur in Latah Creek, but the numbers and distribution are sparse (Edelen & Allen 1998). Low summer flows and high temperatures are thought to be the main limiting factors to salmonid populations today. At present, the Latah Creek fishery is dominated by minnows (Cyprinidae) and suckers (Catostomidae). Based on recent collections, at least 12 species occur in Latah Creek (Edelen and Allen 1998; Laumeyer and Maughan 1973, 1974); 3 of these are introduced…"*

More recent fish surveys and research have documented rainbow, eastern brook and cutthroat trout, and native red-band trout populations in California, Marshall, and Garden Springs Creeks and some of the upper Hangman Creek tributaries (Lee, 2005; CdA Tribe, 2003; McLellan, 2005). Trout have been reported in Indian, Stevens, Trout, and Cottonwood Creeks and in the mainstem of lower Hangman Creek (Lee, 2005). Except for a few individuals, most of these fish were located in tributary reaches or during colder temperature conditions in the mainstem.

Lee (2005) collected 4,299 fish at 62 sites within the Hangman Creek drainage in Washington. Salmonid species made up 20.6% of the fish. However, more than two-thirds of salmonids caught were non-native eastern brook trout in Marshall Creek. Most of the other species were warm-water fish such as dace, shiners, and pikeminnow (52.7%), or suckers (22.8%), although sculpins (3.7%) were found and generally like colder water.

Macroinvertebrate communities are important food sources for several fish species, and they are important processors of organic materials in the aquatic ecosystem. Macroinvertebrate communities are exposed to water quality conditions over all life cycles, and their assemblages can be used to interpret various pollutant effects. The findings of an assessment of macroinvertebrate communities at several sites in Hangman Creek in 1996 and 1997 (Celto, Fore, and Cather, 1998) were corroborated by a recent macroinvertebrate survey conducted by Ecology in 2003 (Ecology, 2005). Ecology (2005) summarized the survey results from three mainstem and four tributary sites as follows:

- California Creek and Marshall Creek had relatively high metric scores (healthier benthic communities):
  - Significantly higher clinger functional group species; higher percentages of ephemeroptera, plecoptera, and tricoptera (EPT) and long-lived species; and higher total richness scores
  - Presence of intolerant or moderately tolerant taxa
- The mainstem sites had relatively low metric scores (less healthy benthic communities):
  - Presence of more tolerant taxa
  - An unusual set of assemblages for a small stream
  - An assemblage of mayflies that are more common in a large open stream or river

Several water quality standards and criteria are designed to protect aquatic communities and their habitat from harm. Criteria are set to protect beneficial uses to fish, shellfish, and crustacean for migration, spawning, and rearing. Wildlife habitat is another beneficial use protected in the standards. Turbidity and temperature are pollutants of concern in the Hangman Creek watershed that can have deleterious effects on aquatic communities.

Turbidity and Sediment

Turbidity is a measure of light refraction in the water and is used to control the amount of sediment and suspended solids. Turbidity is measured in nephelometric turbidity units (NTU). Fish and other aquatic life are affected by turbidity in the water column and sediment that has settled out on the bottom of the waterbody. The effects of turbidity, sediment, and solids on fish and other aquatic life can be divided into four categories: (1) acting directly on the fish swimming in the water and either killing them or reducing their growth rate, resistance to disease, etc.; (2) preventing the successful development of fish eggs and larvae; (3) modifying behavior, natural movements, and migrations; and (4) reducing the abundance of available food.

Suspended sediment and solids may also serve to transmit attached chemical and biological contaminants to waterbodies. Some of the suspended solids are organic materials that decay after they have settled. Too much decaying material can cause oxygen depletion. Toxic chemicals sometime attach to sediments and solids where they can be taken up in the tissue of fish. This can affect the health of humans and wildlife that eat the fish. Turbid waters also interfere with the treatment and use of water as potable water supplies, and can interfere with the recreational use and aesthetic enjoyment of the water.

WA State established turbidity criteria in the water quality standards primarily to protect aquatic life. Two turbidity criteria are established to protect six categories of aquatic communities [WAC 173-201A-200; 2003 edition]. In Hangman Creek and its tributaries the following criteria applies:

To protect the designated aquatic life uses of "Char Spawning/Rearing," "Core Summer Salmonid Habitat," "Salmonid Rearing and Migration" and "Non-anadromous Interior Redband Trout," turbidity must not exceed: A) 5 NTU over background when the background is 50 NTU or less; or B) a 10% increase in turbidity when the background turbidity is more than 50 NTU.

In addition, sediment (suspended sediment or ~~(a component of~~ total suspended solids ~~or~~(TSS) are a significant portion of the total sediment load) to ~~in~~ Hangman Creek can be addressed to control~~led~~ impacts excessive amounts of this pollutant has on ~~under the~~ designated uses as identified in Washington's narrative water quality standards. As previously described, these uses include salmonid spawning, rearing and migration. Although there are currently no numeric criteria for sediment, these ~~The~~ water quality standards limit the effect of sediments on existing and designated aquatic life uses in Hangman Creek in the Toxics and aesthetics criteria.

> *(a) Toxic, radioactive, or deleterious material concentrations must be below those which have potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health…*[(WAC 173-201A-260 (1) (b)]

Temperature

Temperature affects the physiology and behavior of fish and other aquatic life. Temperature may be the most influential factor limiting the distribution and health of aquatic life. Most organisms have fairly narrow ranges of temperatures that can be tolerated. Chemical reactions and metabolism rates also increase with rising temperature, so contaminants can become more toxic. The influence of humans on the terrestrial and aquatic environment can affect aquatic temperature regimes.

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, the criteria are expressed as the highest 7-day average of the daily maximum temperatures (7DADM) occurring in a waterbody.

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition]. As mentioned earlier, Hangman Creek must meet criteria to protect salmon and trout spawning rearing and migration.

The temperature criterion for this designation is as follows:

To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only" the highest 7DADM temperature must not exceed 17.5°C (63.5°F) more than once every ten years on average.

The state uses the criterion to ensure that where a waterbody is naturally capable of providing full support for its designated aquatic life uses, that condition will be maintained. However, the standards recognize that not all waters are naturally capable of staying below the fully protective temperature criteria. When a waterbody is naturally warmer than the criterion, the state provides an additional allowance for additional warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3°C (0.54°F) increase above the naturally higher (inferior) temperature condition.

In addition to the maximum criteria noted above, compliance must also be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the criteria noted above, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to: A) incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge), and B) incremental temperature increases resulting from the combined effect of all nonpoint source activities in the waterbody must not at any time exceed 2.8°C (5.04°F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where the department determines the temperature criteria established for a waterbody would likely not result in protective spawning and incubation temperatures, the following criteria apply: A) Maximum 7DADM temperatures of 9°C (48.2°F) at the initiation of spawning and at fry emergence for char; and B) Maximum 7DADM temperatures of 13°C (55.4°F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

While the criteria generally applies throughout a waterbody, it is not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria. For this reason, the standards direct that one take measurements from well-mixed portions of rivers and streams. For similar reasons, field staff do not take samples from anomalously cold areas such as at discrete points where cold groundwaters flow into the waterbody.

Global Climate Change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Summer streamflows depend on the snowpack stored during the wet season. Studies of the region's hydrology indicate a declining tendency in snow water storage coupled with earlier spring snowmelt and earlier peak spring streamflows (Hamlet et al., 2005). Factors affecting these changes include climate influences at both annual and decadal scales, and air temperature increases. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

Ten climate change models were used to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average warming rate is expected to be in the range of 0.1-0.6°C (0.2-1.0°F) per decade, with a best estimate of 0.3°C (0.5°F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer streamflows are also predicted to decrease as a consequence of global climate change (Hamlet and Lettenmaier, 1999).

The expected changes coming to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool. Stream temperature improvements obtained by growing mature riparian vegetation corridors along streambanks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global climate change – keeping conditions from getting worse. It will take considerable time, however, to reverse those human actions that contribute to excess stream warming. The sooner such restoration actions begin, and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources.

These efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species. As global climate change progresses, the thermal regime of the stream itself will change due to reduced summer streamflows and increased air temperatures.

The state is writing this TMDL to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature associated with global climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future impacts would be to begin now to protect as much of the thermal health of our streams as possible.

Watershed Description

Hangman Creek and its tributaries, Rock Creek and Little Hangman Creek, originate in Idaho and flow northeast into Washington. Hangman Creek is a tributary to the Spokane River. The watershed has three separate regulatory areas:

- The State of Idaho
- The Coeur d'Alene Tribal Reservation, and
- The State of Washington.

Ecology has identified the Hangman Creek watershed as a waterbody with quality and quantity issues. Past water quality studies have shown that Washington State standards for fecal coliform, temperature, pH, and dissolved oxygen are often not met (SCCD 1994, 1999, 2000; Hallock, 1988). Past and current land uses within the watershed are varied and contribute to the problem. Water quality issues, such as stormwater runoff, sedimentation, streambank erosion, urban development, wetland destruction, and agricultural and forestry practices, are all major concerns for the area.

Agriculture has been the dominant land use in the Hangman Creek watershed since the early 1900s. By the early 1920s, a significant portion of the farmable land had been cleared and cultivated for the production of wheat, barley, peas, and lentils. Thousands of acres of forest and riparian areas were cut and cleared (see below). Miles of stream channel were straightened, and new ditches were dug to drain wetlands and quickly move water off the farm fields.

These modifications, along with stream meander cutoff by roads, changed the watershed's hydrological response. The system became stressed with heavy sediment loading, poor water quality, and accelerated streambank erosion. The altered hydrology produces flashy, and sometimes damaging, stream flows during the winter and spring months. Peak winter and spring flows are generally 4,000 to 10,000 cubic feet per second (cfs), with flows up to 20,000 cfs. During the summer months, the baseflow decreases significantly throughout a majority of the watershed (daily average flows of less than one cfs have been recorded).

Several point and nonpoint issues have been identified and discussed through past Hangman Creek water quality studies. Historically, the sources targeted in the Hangman Creek watershed for reduction have been primarily nonpoint sources. Some examples include conservation tillage in croplands, streambank restoration, and riparian restoration.

The Hangman Creek Watershed contains ten permitted facilities in Washington. Four of these facilities (Badger Lake Estates, Liberty School District, Hangman Hills, and Upper Columbia Academy) have state wastewater discharge permits to discharge to ground. The six remaining wastewater treatment plants (WWTPs) have NPDES permits to discharge to surface water (Table 4).

Table 4. Wastewater treatment plants with permits to discharge to Hangman Creek

WWTP	Permit Number	Discharges to
City of Cheney	WA0020842C	Wetland drains to Minnie Creek
Town of Fairfield	WA0045489C	Rattler Run Creek
Freeman School District	WA0045403C	Little Cottonwood Creek
Town of Rockford	WA0044831C	Rock Creek
Town of Spangle	WA0045471B	Spangle Creek
City of Tekoa	WA0023141C	Hangman Creek

All of the WWTPs monitor effluent and report results to Ecology as required in their NPDES permits. Each of the facility's permits were renewed or extended in 2007. The NPDES permits for these facilities have some ammonia and chlorine water quality-based effluent limits. Suspended solids, biochemical oxygen demand, and pH are technology-based. Most fecal coliform limits are more restrictive than technology-based. Other than Cheney, effluent temperature and nutrients are not regulated in the permits.

In addition, three entities within the watershed are covered by the Municipal Stormwater Permit. This NPDES permit regulates pollutants carried to waterbodies by stormwater. Spokane County, the City of Spokane, and the Washington State Department of Transportation (WSDOT) are all Phase 2 municipal separate stormwater sewer system (MS4) permit holders. The NPDES permit coverage is limited to the urban and urban growth areas of the city and county. The WSDOT permit primarily applies to state routes and interstates within the Phase 2 areas, but WSDOT will expand monitoring and treatment to all of its roads in TMDL-designated areas in the near future.

Historic Hangman Creek vegetation

The water quality degradation documented throughout the watershed raises questions about the historical conditions of the watershed. The Spokane County Conservation District (SCCD) evaluated pre-settlement watershed conditions using historic plant community cover as described in early section line surveys (2003b). The section line surveys were part of the Public Land Survey System conducted under standards set forth in the 1785 Land Ordinance (BLM, 2003). The rectangular survey system, also known as the cadastral survey, subdivided public lands into townships, ranges, and sections across the western United States.

The original land surveys of Washington were conducted by the Surveyor General's Office in Olympia, WA during the late 19th Century. Similarly, surveys of the Idaho portions of the watershed were supervised by the Surveyor General's Office in Boise, ID in the early 20th Century. They recorded observations in their field notes, drew plats, and designated boundaries along the line walked. In general, most surveyors' field notes included descriptions of vegetation, landforms, soil type, water availability, and suitability for settlement. These qualitative descriptions of vegetation found in the field notes, along with the hand-drawn plats, were used to estimate the historic vegetation cover for the Hangman Creek Watershed.

The historical vegetative communities in the Hangman Creek watershed prior to settlement were significantly different than today's (Table 5). The watershed was primarily covered with rolling hills of bunchgrass prairie that extended into scattered populations of Ponderosa pine forests. The Ponderosa pine communities often included a shrub understory such as snowberry and wood's rose. Historically, the streams, springs, and drainages were densely vegetated with various shrubs and small trees including: hawthorn (*Crataegus*), willows (*Salix*), aspen and cottonwood (*Populus*), alders (*Alnus*), serviceberry (*Amelanchier alnifolia*), and chokecheery (*Prunus virginiana*) (SCCD, 2003b).

Table 5: Land use changes in Hangman Creek watershed (1870-2003) from SCCD (2003b).

Sub-watershed	Land Use	Land Uses (percent of sub-watershed area)		Net Change (pre-settlement to current, in percent)
		Pre-settlement	Current	
California Creek	Agriculture	0	55	55
	Developed	0	2	2
	Forested	96	23	-73
	Rock/Transitional	0	0	0
	Shrub/Steppe	4	19	15
	Wetland or Lake	0	0	0
Lower Hangman Creek	Agriculture	0	30	30
	Developed	0	14	14
	Forested	67	18	-49
	Rock/Transitional	0	0	0
	Shrub/Steppe	29	36	7
	Wetland or Lake	3	0	-3
Marshall Creek	Agriculture	0	26	26
	Developed	0	6	6
	Forested	71	34	-37
	Rock/Transitional	0	1	1
	Shrub/Steppe	22	27	5
	Wetland or Lake	5	2	-3
Rock Creek	Agriculture	0	81	81
	Developed	0	1	1
	Forested	71	10	-61
	Rock/Transitional	0	0	0
	Shrub/Steppe	29	7	-22
	Wetland or Lake	1	0	-1
Upper Hangman Creek	Agriculture	0	70	70
	Developed	0	1	1
	Forested	48	21	-27
	Rock/Transitional	0	1	1
	Shrub/Steppe	51	6	-45
	Wetland or Lake	0	0	0

Agriculture has become the dominant land use for the watershed at over 275,000 acres. This more than doubles the pre-settlement prairie and forested areas combined. Forest land cover was reduced between 50 to 75% for all sub-watersheds, with the exception of Rock Creek, which was reduced approximately 86%. The harvest and conversion of these forested areas, especially in headwater tributaries, probably had significant impacts to the hydrology of the watershed (SCCD, 2003b).

Watershed geologic conditions

Bedrock in the lower watershed is mainly Miocene basalt flows with pockets of Tertiary biotite granite and granodiorite (WDNR, 1998). During the Miocene, the basalt flows would periodically dam rivers and form lakes. Material deposited in these lakes formed the siltstones and sandstones of the Latah Formation. Pleistocene glacial deposits produced large amounts of wind-blown silt, known as loess. This wind-blown silt accumulated up to 200 feet over most of the basalt flows and formed dune-shaped hills.

During the late Pleistocene period, lobes from ice sheets in northern Washington, Idaho, and Montana blocked several major drainages and produced extensive lakes. The largest lake produced was Glacial Lake Missoula, located near present day Missoula, Montana; at one time it covered over 3,000 square miles. Periodically the ice dams broke, and significant floods occurred in Washington, including in the lower Hangman Creek watershed. There were over 40 separate flood events from Glacial Lake Missoula (Waitt, 1980). The floods left major channels in the region, removed the loess deposits covering the basalt, and deposited much of the sand, gravel, cobble, and boulders found in the lower reaches of Hangman Creek.

Easily erodible material is found throughout the Hangman Creek watershed. The unconsolidated material consists of three major deposits. Glacial Lake Missoula flood deposits of sand, gravel, and cobbles; reworked Missoula flood deposits, and the loess deposits found in the upper watershed (Buchanan and Brown, 2003). The Missoula Flood deposits extend from the Spokane River confluence to the Rock Creek confluence. Along with the unconsolidated sediments, the weakly lithified sedimentary rocks of the Latah Formation are also subject to stream erosion.

The Latah Formation consists of fine laminations of silts and clays with low permeability that tends to perch water above the formations. Bank slumping occurs as water erodes sediment from between the confining silt and clay layers. The silts and clays are resistant bands that tend to form vertical banks above them. Poorly consolidated sands and gravels within the Latah Formation tend to wash out, undercutting and exposing the silt and clay layers. This undercutting can result in block slumps and rapid bank loss.

The Lake Missoula flood deposits consist of sorted-to-unsorted, silt sands, gravels, cobbles, and boulders. The unconsolidated material erodes easily along streams, producing steep unstable slopes over 100 feet high. The major type of erosion is toe failure caused by the stream removing the material at the base of the streambank. Once the toe is removed, the bank is over-steepened. The over-steepened bank fails and deposits large amounts of material directly into the stream. The deposited material is available to be mobilized under most flow conditions (Figure 3).

Figure 3. Material deposited from Missoula floods (photo by SCCD).

Post Missoula flood alluvium generally overlies all the other sediment layers. The post Missoula flood material is reworked flood deposits and is unconsolidated and easily eroded. The deposits are generally terraces that originally formed as flood plains when Hangman Creek was downcutting through the flood alluvium. The erosional characteristics are similar to the Lake Missoula flood deposits discussed above, but are more cohesive because a significant amount of sand and gravel has been removed.

Soils within the Hangman Creek watershed have formed from a wide variety of materials. The main soils are deep soils that formed from the silty loess deposits. The soils are generally medium to fine-textured, with moderate to slow permeability. The soils have high to moderate water-holding capacity. Other parent materials for the soils include volcanic ash, glacial deposits, alluvium deposited by streams, and material weathered from basaltic, granite, and metamorphic bedrock.

Watershed physiographic provinces

The Hangman Watershed can be divided into three major physiographic provinces (Figure 4): the upper Palouse soil section (headwaters to RM 32.8); the middle basalt canyon section (RM 32.8 to 18.8); and the lower Missoula flood deposit section (RM 18.8 to 0.0). The upper Palouse section extends from the headwaters of Hangman Creek (formed by the Idaho Batholith) through the rolling loess hills of the Palouse region. The upper section represents a river system that is bedrock controlled in many reaches. Some human influence can be seen, but the main channel morphology is generally controlled by existing bedrock.

The middle basalt canyon consists of steep canyons formed as Hangman Creek cuts down through the Miocene basalt flows. The stream reaches are generally represented by steep gradients and little flood plain development. Human influence is minor, with some grazing in the accessible reaches.

Hangman Creek then flows through sedimentary hills of sand, gravel, and cobbles deposited by the ancestral glacial lake Missoula floods. The third physiographic province is dominated by Missoula flood deposits and terraces of reworked Missoula flood deposits. This area represents a young system that has not had time to form an extensive flood plain system by fully reworking the deposited Missoula flood sediments. Human influence is significant with road and housing development from the expanding City of Spokane on the existing flood plain.

Geologic and man-made limitations

Several geologic and climatic conditions combine to provide a unique setting for the Hangman Creek watershed. The environmental conditions include low stream flows during the summer, easily eroded streambanks, and low groundwater storage and baseflow. These conditions limit what can be done for some areas of the watershed.

Extremely low stream flows in the late summer (below one cubic foot per second) can limit the benefits that would normally occur with the implementation of many of the identified best management practices (BMPs). The BMPs help reduce loading primarily during higher winter and spring flow events, but they may also help reduce any secondary remobilization during the low-flow months. Low streamflow, groundwater storage, and baseflow also limit riparian and wetland benefits.

Easily eroded streambanks that are unstable at moderate to low flows (such as the sand banks deposited from the Missoula floods) are generally hard to stabilize. BMPs for these banks can be costly and provide a low cost/benefit ratio.

Anthropogenic limitations include the hydrologic effects of meander cutoffs and stream modifications by roads, agricultural fields, residences, and riparian alteration. Highway 195 has had significant hydraulic effects in the northern physiographic province of the watershed. Several changes to the stream length, vegetation, and meanders have reduced the dissipation of stream energy and increased erosion along this reach of Hangman Creek.

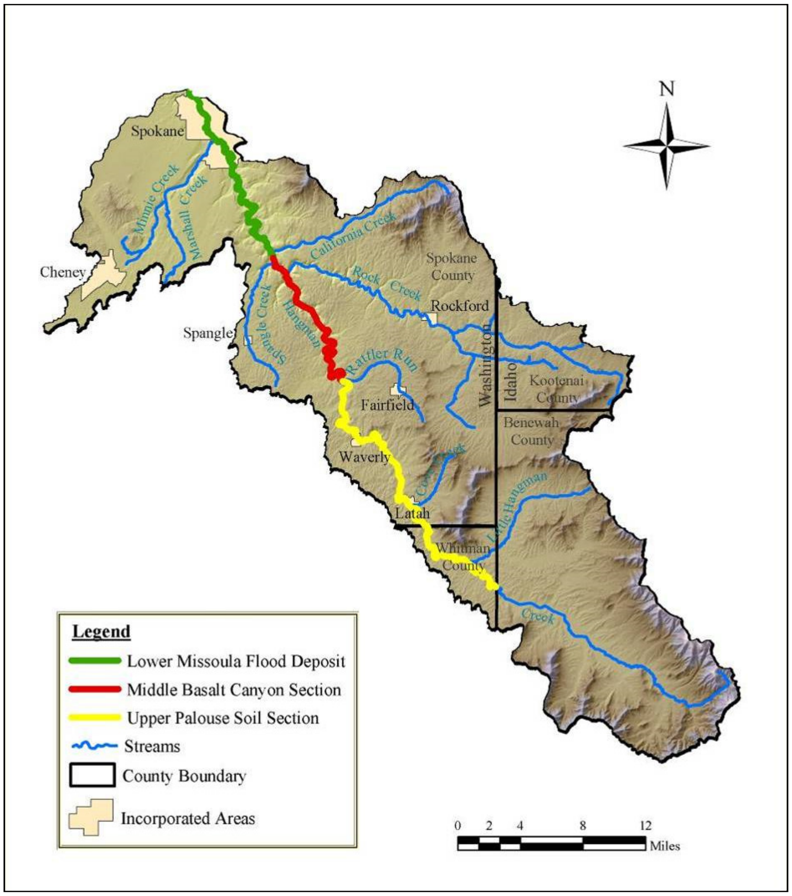

Figure 4. Hangman Creek physiographic provinces (SCCD, 2005b).

Goals and Objectives

Project goals

The goal of this TMDL is to develop a plan to meet water quality standards for fecal coliform bacteria, temperature, and turbidity in Hangman Creek and its tributaries. The following technical analysis and implementation strategy will accomplish this goal by:

1. Characterizing fecal coliform bacteria, heat, and suspended sediment loading from various parts of the basin.
2. Incorporating previously conducted temperature modeling work into a temperature TMDL.
3. Setting of total maximum daily load (TMDL) allocations for fecal coliform, temperature, and suspended sediment/turbidity.
4. Outlining an implementation strategy.

Study objectives

Several objectives were set for attaining the project goal. These involved both technical analysis and the implementation process. The technical analysis objectives were led by the Ecology Environmental Assessment Program project manager and SCCD field staff. The implementation process will continue to be led by the Ecology Eastern Regional Office (ERO) Water Quality Program TMDL lead and SCCD staff.

Objectives for the technical analysis included the following:

- Review background information and historical water quality data to:
    - understand geology, hydrology, climate, land use, and political influences on the water quality problem
    - evaluate additional data needs
    - help determine the seasonal and geographical limits to the problem
    - determine trends
    - focus investigations on potential sources
- Engage local agencies for additional data, expertise, and experience.
- Integrate SCCD field work with work performed by Ecology and other agencies in the basin for efficient use of resources.

Objectives for achieving water quality through implementation activities include the following:

- Inform the community about the TMDL process through meetings and development of a local advisory committee.
- Gather input from local residents to create a plan with strategies shown to improve water quality.
- Meet water quality standards by following a locally developed plan.

- Create and maintain communication with the public and representatives of the various planning processes.
- Partner with local groups to apply BMPs that improve water quality.
- Provide technical and financial assistance when possible.

Related Goals

This TMDL study also included collecting data and analyzing phosphorus loading in the watershed. The loading analysis used the same methods and models as this report's turbidity and suspended sediment TMDL analysis. The focus was to determine what reductions are necessary to achieve phosphorus allocations at the mouth of Hangman Creek set by the draft *Spokane River Dissolved Oxygen TMDL*. The watershed phosphorus loading analysis to the Spokane River was presented to the Hangman Creek Advisory Committee to assure strategies in this TMDL also help reduce phosphorus.

The phosphorus analysis is not included here because it did not explore the role of phosphorus in causing pH or dissolved oxygen criteria violations in the Hangman watershed. The phosphorus loading analysis will be presented in a separate report expected to be published in 2009.
A dissolved oxygen, pH, and nutrient TMDL for Hangman Creek will be completed in 2009–2010.

Field Data Collection

The technical analysis used to evaluate the TMDL was based on historic and recently collected data. Previous studies and monitoring include:

Washington State Department of Ecology (Ecology)

- Water Quality Monitoring Station #56A070 Hangman Creek at Mouth. This station is considered a long-term station (1970–2005).
- Water Quality Monitoring Station #56A200 Hangman Creek at Bradshaw Road. This station was sampled only from October 1998 through September 1999.
- Tekoa Wastewater Treatment Plant receiving water survey in 1988 (Carey, 1989)
- Benthic macroinvertebrate sample collections in Hangman Creek, Marshall Creek, and California Creek in 2004.

Spokane County Conservation District (SCCD)

- Basin-wide water quality study (1994–1997). Six mainstem and tributary stations.
- Sediment Study (1998-1999). Suspended sediment and bedload concentrations.
- Paired watershed BMP evaluation data (1997-1998).
- Instream Flow Study. Temperature, flows (2002).
- Seepage run flow and water quality data (2001-2002).

The historic data include Ecology's sampling at ambient monitoring sites (noted above) and from the SCCD sampling at six stations from October 1, 1994 through September 30, 1997.

The SCCD stations sampled were:

- Hangman Creek at State Line (Road)
- Little Hangman Creek
- Rattler Run Creek
- Hangman Creek at Bradshaw Road
- Rock Creek at Jackson Road
- Hangman Creek at Keevy Road

Recent sampling by SCCD for the development of this TMDL included the Hangman Creek mainstem at 11 sites, Cove Creek at one site, Rock Creek at two sites, California Creek at two sites, Spangle Creek at one site, and Marshall Creek at two sites. Sampling was from December 2003 through August 2004. All data collected under the current sampling were collected under an approved Quality Assurance Project Plan (SCCD, 2003a). These data will be discussed in the *Results and Discussion* section.

Study Methods

Data collection

Water quality and related information from past routine monitoring and intensive studies (1970s – 2002) mentioned in the previous section, *Field Data Collection,* were brought together for this evaluation. Several sources of data were used from several government agencies or from agency-sponsored studies. These are summarized below.

The SCCD performed a comprehensive monitoring study of the watershed from December 2003 to August 2004 (SCCD, 2005a). The study was conducted under an approved Quality Assurance Project Plan (SCCD, 2003a). The goal of the study was to collect water quality data in preparation for the TMDL evaluations on fecal coliform, turbidity, and total suspended solids. Data were also collected to evaluate phosphorus distributions in the watershed.[1] Monthly and targeted storm-event monitoring was accomplished at 19 sites in the watershed (Figure 5 and Table 6). An additional ten sites were monitored only on a few occasions for site-specific purposes (Figure 6 and Table 7).

Table 4 lists the six WWTPs in the watershed. Fairfield, Rockford, and Tekoa's effluents were sampled monthly from January through July if the WWTP was discharging effluent (SCCD, 2005a). Tekoa WWTP is the only one among the three that discharges to Hangman Creek year-round. Cheney WWTP discharges to a wetland connected to Minnie Creek, a tributary of Marshall Creek. Spangle WWTP discharges to Spangle Creek, an intermittent stream. Freeman School District WWTP only intermittently discharges to a tributary in the Rock Creek sub-watershed. Effluent monitoring data on record at Ecology's ERO from the six WWTPs were used for the study.

Temperature monitoring and modeling were contracted to Hardin-Davis, Inc. by the Hangman (Latah) Creek Watershed (WRIA 56) Planning Unit in 2002. Continuous temperature and flow monitoring equipment was installed by the SCCD for the temperature modeling. The model used was the Stream Network Temperature Model (SNTEMP). Hardin-Davis (2003) conducted a one-day hydrogeologic evaluation, installed mini-piezometers, and tested the hydraulic conductivity of the bed sediments. Physical habitat measurements were taken by Hardin-Davis from five characteristic reaches in the study area. Seepage runs, monitoring of stream flows at several locations over one day, were conducted by the SCCD on three occasions in 2001 and 2002 (SCCD, 2005a).

[1] Watershed phosphorus loading to the Spokane River will be discussed in a separate technical report due in 2009.

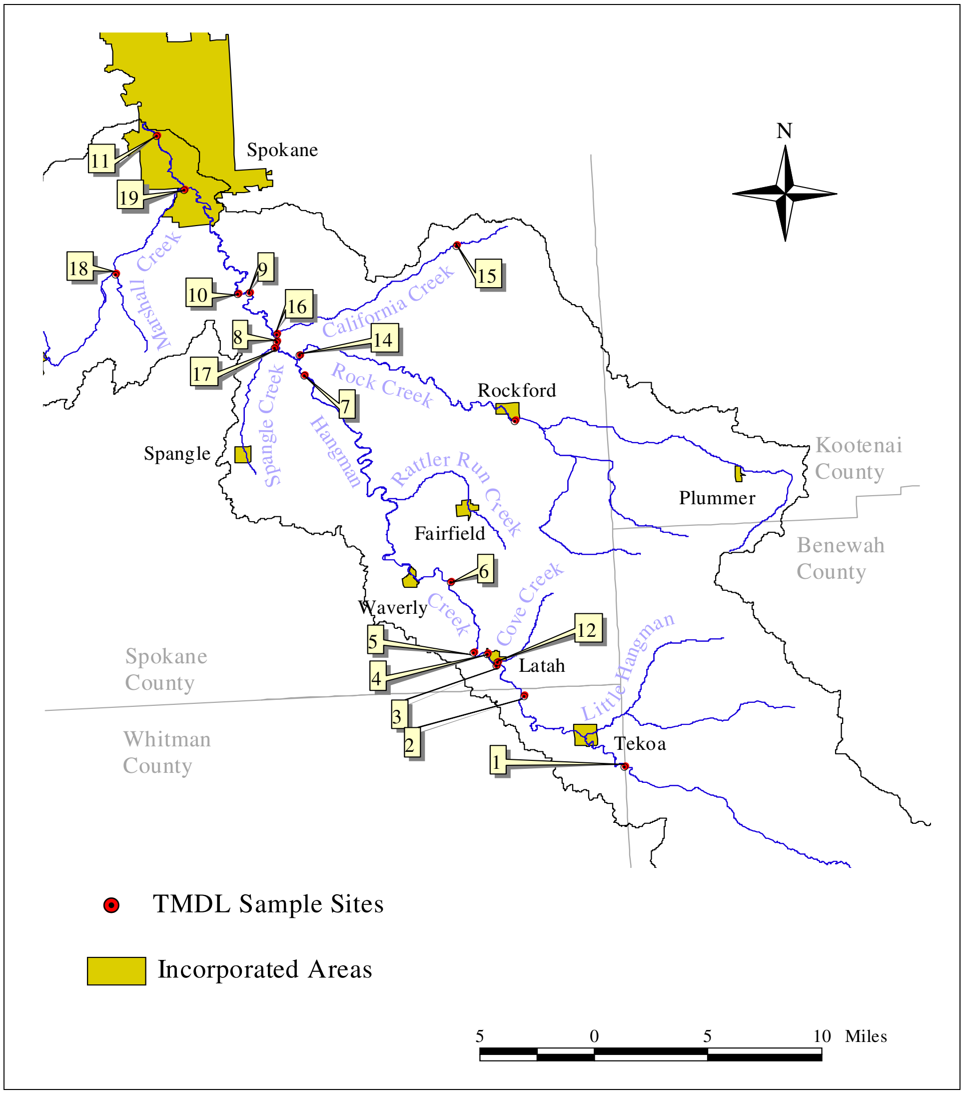

Figure 5. Water quality sampling sites in the Hangman Creek watershed used by the Spokane County Conservation District in 2003-2004 (SCCD, 2005a).

Table 6. Sites sampled by the Spokane County Conservation District in the Hangman Creek watershed for the total maximum daily load study from December 2003 to August 2004.

Site Name	Site Location (Section, Township, Range)	Site Number on Figure 5
Hangman Creek at State Line (Road)	Section 30, T20N, R46E	1
Hangman Creek at Fairbanks Road	Section 9, T20N, R45E	2
Hangman Creek at Marsh Road	Section 30, T21N, R45E	3
Hangman Creek at Spring Valley Road	Section 30, T21N, R45E	4
Hangman Creek at Chapman Road	Section 30, T21N, R45E	5
Hangman Creek at Roberts Road	Section 1, T21N, R44E	6
Hangman Creek at river mile 21.0	Section 13, T23N, R43E	7
Hangman Creek at Duncan	Section 11, T23N, R43E	8
Hangman Creek upstream of Hangman Valley Golf Course	Section 28, T24N, R43E	9
Hangman Creek downstream of Hangman Valley Golf Course	Section 28, T24N, R43E	10
Hangman Creek at the USGS gage	Section 24, T25N, R42E	11
Cove Creek	Section 30, T21N, R45E	12
Rock Creek at Rockford	Section 33, T23N, R45E	13
Rock Creek at the mouth	Section 12, T23N, R43E	14
California Creek near Marsh Road	Section 18, T24N, R45E	15
California Creek at the mouth	Section 2, T23N, R43E	16
Spangle Creek at the mouth	Section 11, T23N, R43E	17
Marshall Creek at McKenzie Road	Section 22, T24N, R42E	18
Marshall Creek at the mouth	Section 6, T24N, R43E	19

All sites were sampled monthly except Hangman Creek at Fairbanks Road, Marsh Road, Spring Valley Road, and Chapman Road.

The sites at Fairbanks Road, Marsh Road, Spring Valley Road, and Chapman Road were added to evaluate potential fecal influence from the Town of Latah and from local livestock.

Two high-flow events were sampled on January 30, 2004 and February 19, 2004. Both events peaked at 4,020 cfs (provisional data) as measured at the USGS station.

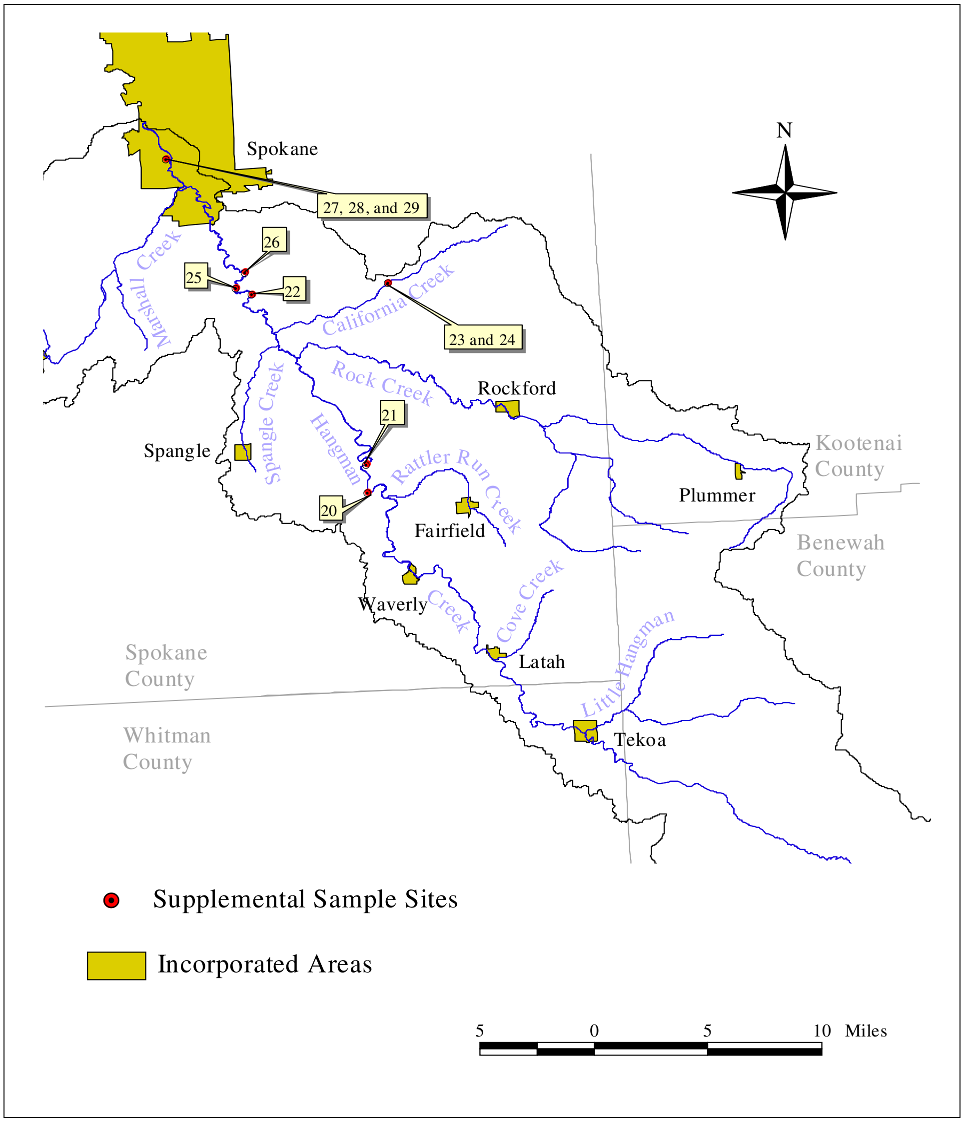

Figure 6. Additional water quality monitoring sites in the Hangman Creek watershed used by the Spokane County Conservation District for special investigations in 2003-2004 (SCCD, 2005a).

Table 7. Special sites sampled by the Spokane County Conservation District in the Hangman Creek watershed for the TMDL study from December 2003 to August 2004.

Sample Location	Site Location (Section, Township, Range)	Site Number on Figure 6	Sample Months
Hangman Creek at North Kentuck Trail	Sec. 17 T22N, R44E	20	Jan. 2004 event
Hangman Creek at Keevy Road	Sec. 8 T22N, R44E	21	Dec. 2003, Jan. 2004, Jan. 2004 event, Feb. 2004, Mar. 2004
Stevens Creek at the mouth	Sec. 28 T24N, R43E	22	Feb. 2004, Mar. 2004
Ditch above Madison Road near Valleyford	Sec. 33 T24N, R44E	23	Jan. 2004 event
Ditch below Madison Road near Valleyford	Sec. 33 T24N, R44E	24	Jan. 2004 event
Hangman Creek upstream of Hangman Hills WWTP	Sec. 28 T24N, R43E	25	Feb. 2004 event
Hangman Creek downstream of Hangman Hills WWTP	Sec. 28 T24N, R43E	26	Feb. 2004 event
Cold Spring near 21st and Inland Empire Way - upper	Sec. 25 T25N, R42E	27	Feb. 2004, Mar. 2004
Cold Spring near 21st and Inland Empire Way - middle	Sec. 25 T25N, R42E	28	Mar. 2004
Cold Spring near 21st and Inland Empire Way - lower	Sec. 25 T25N, R42E	29	Feb. 2004, Mar. 2004

Hangman Creek was sampled upstream and downstream of the Hangman Hills treatment plant to evaluate potential fecal and nutrient contributions.

The Cold Spring sites were sampled to evaluate the water quality of a significant spring to the Hangman Creek mainstem.

Stevens Creek was sampled when there was flow in the creek.

Hangman Creek at Keevy Road was the upstream sample point to evaluate potential livestock influence. The site was changed to evaluate a smaller area for influence.

The Madison Road sites were sampled to evaluate runoff from a disturbed area where sediment-laden water was flowing below the road.

The temperature monitoring sites for the SNTEMP study are listed in Table 8. The final report by Hardin-Davis, Inc. was reviewed and accepted by the Hangman Creek Watershed Planning Unit for inclusion into its final water resources management plan (SCCD, 2005b).

Ecology's Environmental Assessment Program decided the SNTEMP model analyses could be used as the foundation for a temperature TMDL evaluation in the Hangman Creek watershed. Additional data were necessary to develop thermal load allocations along the creek.

The SCCD conducted canopy closure measurements using a densiometer at 19 sites along the creek in September 2006 (Table 9). The measurements were used for ground-truthing the shade values estimated from the aerial ortho-photographs and shade model. Measurements were taken in four directions on the right, left, and middle thirds of the creek on seven transects with convex densiometers. The transects were located at 100, 300, and 500 feet upstream and downstream of a centerline transect (1000 feet area in total). Bank vegetation type, density, average height, and overhanging distance data were collected along with basic channel measurements.

Densiometer measurements were converted to percent canopy closure estimates using Timber/Fish/Wildlife stream ambient monitoring field methods (Ralph, 1990). Densiometer readings and canopy closure estimates are summarized in Appendix B.

Data management and analysis

Results of the 2003-2004 Hangman Creek monitoring project were managed according to an approved Quality Assurance Project Plan (SCCD, 2003a). All data were reviewed, verified, and validated. Data were submitted to Ecology Environmental Information Management (EIM) system. These data and are available under User ID G0400196 and Study Name Hangman Creek TMDL Project at http://apps.ecy.wa.gov/eimreporting/Search.asp. The data summary report (SCCD, 2005a) is available on Ecology Hangman Creek TMDL website at www.ecy.wa.gov/programs/wq/tmdl/hangman_cr/wq_final_report040505.pdf.

Data from several sources for the water quality assessment were managed using Microsoft® Office Excel (2003) spreadsheets. Several tools were used to examine the data. Statistical tests were run using WQHYDRO (Aroner, 2007) and Microsoft® Office Excel (2003) software. Multiple regression analyses were run using an analytical method by Cohn (1988) with SYSTAT software. The WARMF model was run with software provided through the EPA Office of Environmental Research and originally developed by the Systech Corporation (Systech, 2001).

The WARMF model was constructed and calibrated for the Hangman Creek watershed under an EPA contract by the Cadmus Group and CDM (2007). GIS, water quality, climatological, and land-use data were gathered from the most reliable and recent sources. Model calibration and data refinement continued after receiving the model with additional input provided by Ecology and members of the Hangman Creek Advisory Committee.

Table 8. Temperature monitoring sites used to calibrate the SNTEMP model for Hangman Creek (Hardin-Davis, 2003).

Station	River mile	River km	Elevation (ft)	Elevation (m)	Latitude (deg)	Latitude (RAD)
Hangman Creek at Marne Bridge, Riverside Avenue	0.4	0.6	1730	527	47.65	0.83165
Hangman Creek at Kampas Bridge near Cheney Spokane Rd	3.6	5.8	1780	543	47.63	0.83121
Hangman Creek at U.S. 195, downstream of Qualchan Golf Course	4.5	7.2	1795	547	47.62	0.83107
Hangman Creek at Yellowstone Pipe Line	8.8	14.2	1830	558	47.58	0.83049
Hangman Creek at Hangman Valley Golf Course	13.8	22.2	1855	566	47.54	0.82976
Hangman Creek at Valley Chapel Rd	18.2	29.3	1887	575	47.52	0.82932
Hangman Creek at Duncan	18.7	30.1	1896	578	47.51	0.82918
Hangman Creek at Latah Rd	22.2	35.7	1945	593	47.47	0.82845
Hangman Creek at Keevy Rd near Mt. Hope, WA	29.2	47.0	2195	669	47.42	0.82758
Hangman Creek at W. Bradshaw Rd near Fairfield, WA	32.9	53.0	2295	700	47.38	0.82700
Hangman Creek at Hays Rd near Waverly, WA	35.5	57.2	2325	709	47.36	0.82656
Tributaries						
Marshall Creek at U.S. 195	0.4	0.6	1820	555	47.62	0.83107
California Creek at Elder Rd	0.1	0.2	1975	602	47.52	0.82932
Rock Creek at Valley Chapel Rd	0.3	0.5	1915	584	47.49	0.82889

Table 9. The most upstream transect location of 19 sites where canopy cover was measured on September 20–22, 2006 by the Spokane County Conservation District. Measurements were taken at seven transects downstream at each site along 1000 feet of Hangman Creek.

Station	River Mile	Description
1	0.6	2000 feet upstream of Marne Bridge
2	3.6	1050 feet upstream of the Avista Bridge
3	4.5	500 feet upstream of Marshall Creek confluence with Hangman Creek
4	5.7	Upstream end of the Bridlewood housing development
5	8.8	500 feet from the Yellowstone Pipeline crossing
6	13.8	Hangman Valley Golf Course
7	18.2	Just downstream of California Creek confluence with Hangman Creek
8	18.7	Approximately 1.5 miles upstream of Valley Chapel Road bridge
9	20.2	Just downstream of Rock Creek confluence with Hangman Creek
10	22.5	Approximately 2 miles upstream of Rock Creek confluence
11	29.2	500 feet upstream of Keevy Road bridge
12	31	1000 feet upstream of North Kentuck Road bridge
13	32.9	500 feet upstream of West Bradshaw Road bridge
14	35.5	500 feet upstream of Hays Road bridge
15	37	1000 feet upstream of Spangle-Waverly Road bridge
16	38	1500 feet downstream of Prairie View Road bridge
17	39.5	Approximately 1.5 miles upstream of Waverly
18	41.6	1000 feet upstream of Roberts Road bridge
19	47	2000 feet upstream of Spring Valley Road bridge

Seasonal Variation and Critical Conditions

Clean Water Act Section 303(d)(1) requires that TMDLs "be established at the level necessary to implement the applicable water quality standards with seasonal variations." The current regulation also states that determination of "TMDLs shall take into account critical conditions for streamflow, loading, and water quality parameters" [40 CFR 130.7(c)(1)]. Finally, Section 303(d)(1)(D) suggests consideration of normal conditions, flows, and dissipative capacity.

The seasonal variation and critical conditions vary somewhat for each of the TMDL pollutants discussed in this report. Therefore, the critical condition is addressed as a separate element during the discussion of each pollutant. The analyses of each pollutant also include comparisons to normal conditions.

Study Quality Assurance Evaluation

Most of the data used for this TMDL technical report were collected under a Quality Assurance Project Plan (QAPP) or with quality control and quality assurance elements (SCCD, 2000 and 2003a; Hallock and Ehinger, 2003). Some information was assumed to be collected under standard protocols, but documentation was not verified (e.g., National Climatic Data Center meteorology data and USGS gage data).

The 2003-2004 field data collected by the SCCD operated under a QAPP reviewed and approved by Ecology (SCCD, 2003). Both field blanks and replicate samples were used to measure sample bias and variability. Bias is the systematic error inherent in a method or measurement system. The variability is the random error in independent measurements as the result of repeated application of the process under specific conditions. The QAPP used a random design to estimate the typical or "representative" quality of the environmental data (SCCD, 2003).

Blank samples were submitted to the Spokane Tribal Laboratory[2] to measure the unintentional introduction of the target analyte into the sample. The blank samples consisted of de-ionized water obtained from the Spokane Tribal Laboratory in dedicated amber glass bottles. The blank water was free of the analytes of interest and was used to test for contamination. All blank samples were kept refrigerated until used in the field.

Blank analysis was conducted for total suspended solids (TSS), turbidity, nitrite, nitrate, ammonia, and total phosphorus. All blank analysis for TSS, nitrite, and nitrate were below the detection limit. All analyses for ammonia were at the detection limit of 0.01 mg/L. All turbidity analysis had a measurable concentration with a high concentration of 0.87 NTU and a mean concentration of 0.067 NTU. Total phosphorus had one sample below the detection limit of 0.005 mg/L, one at the detection limit, and one sample at 0.013 mg/L (Table 10). None of the phosphorus data were qualified since sample concentrations were much higher than the blank that day. Ammonia blanks are difficult to keep uncontaminated below 0.01 mg/L in a laboratory setting.

Table 10. Blank analysis results

Parameter	Blank-1	Blank-2	Blank-3
Total Suspended Solids (mg/L)	<2	<2	<2
Turbidity (NTUs)	0.87	0.32	0.82
Nitrite (mg/L)	<0.01	<0.01	<0.01
Nitrate (mg/L)	<0.01	<0.01	<0.01
Ammonia (mg/L)	0.01	0.01	0.01
Total Phosphorus (mg/L)	0.005	<0.005	0.013

NTU is Nephelometric Turbidity Units.
mg/L is milligrams per liter.

[2] The Spokane Tribal Laboratory is accredited by Ecology for general chemistry and microbiology including nutrients and fecal coliform.

Replicate samples consisted of two or more samples that were considered to be essentially identical in composition. The replicate samples were collected, processed, transported, and analyzed the same way. Sample volumes, times, equipment, and personnel were kept the same whenever possible. Concurrent replicates, samples that were collected at the same time, were generally collected. Some sequential replicates, samples collected one after another, were collected when concurrent sampling was not possible.

The replicate sample variability was estimated using a piecewise linear model (USGS, 2003). The replicate data were split into two groups based on ranges of mean concentration. The mean standard deviation and relative standard deviation for each range were computed. The results provide estimates of the variability by using either the standard deviation or relative standard deviation, whichever describes the data best. The break point is the sample concentration where the sample result changes from being better described using the standard deviation to being better described using the relative standard deviation (Table 11).

Table 11. Replicate analysis results and 90% confidence limits

Parameter	Standard Deviation		Relative Standard Deviation		Break Point	90% Certainty Evaluation	
	Statistical Value	Number of Replicates	Statistical Value	Number of Replicates		Limit	Exceedance Value
TSS	0.663	32	13.3	6	8.5	100	85.5
Turbidity	0.338	32	2.52	6	11	50	48.4
Nitrate-N	0.00898	27	1.31	11	3.0	10	9.84
Ammonia-N	0.00265	32	1.39	6	0.04	1.72	1.69
Total P	0.0026	28	2.58	10	0.1	0.1	0.097
Fecal coliform	29.2	34	28	12	150	200	147.2

All values are milligram per liter except for fecal coliform, which is colonies per 100 ml, and turbidity which is Nephelometric Turbidity Units (NTUs).

TSS is total suspended solids, and Total P is total phosphorus as phosphorus.

The break point is the sample concentration that divides the replicate samples into two groups, one that uses the standard deviation and one that uses the relative standard deviation to define the sample variance.

The exceedance value is the value below which it can be concluded with 90% certainty that the true concentration in the stream did not exceed the concentration limit listed in the "Limit" column.

The statistical value is the mean standard deviation or relative standard deviation for the number of replicate samples.

For the parameter limit in Table 11, an exceedance value was estimated based on the replicate analysis. The exceedance value is the value where it can be concluded that the true concentration in the stream did not exceed the listed limit (with a 90% certainty). For example, if the nitrate value in a sample was less than 9.84 mg/L, then even with the variability associated with the sampling, it is 90% certain that the true value in the stream did not exceed 10.0 mg/L. If the sample value is between 9.84 and 10.0 mg/L, it cannot be concluded (with 90% certainty) that the true concentration in the stream did not exceed the 10.0 mg/ L limit.

Procedures for temperature data collected for the 2002 watershed study were well documented (Hardin-Davis, 2003). The study plan was reviewed by Ecology's Eastern Regional Office Shorelands and Environmental Assistance Program, but no formal QAPP was written and reviewed. The SNTEMP modeling conducted by Hardin-Davis (2003) required calibration to temperature data recorded at 14 sites in the watershed (Table 8). Calibration for the model required some manipulation of wind speed to account for the difference between local and Spokane Airport air temperatures. According to Hardin-Davis (2003), the median absolute error between simulated and observed temperatures was 0.56°C, and 79% of the errors were less than 1°C.

Results and Discussion

Hydrology

Monthly median discharge in Hangman Creek from 1948 to 2005 exhibits a statistically significant, but small, decline (Figure 7). However over shorter periods of the record, some years show no statistically significant decline in flows (1980 and 2005) or show significant declines (1995-2005). The record over the past 12 years demonstrates a high degree of flow variability (Table 12) in Hangman Creek. Mean annual discharge varied from 32 to 629 cfs. The historical 90th percentile daily flow was surpassed 111 days in water year 1997, but never in 1994 and only six times in 2005 (Table 12).

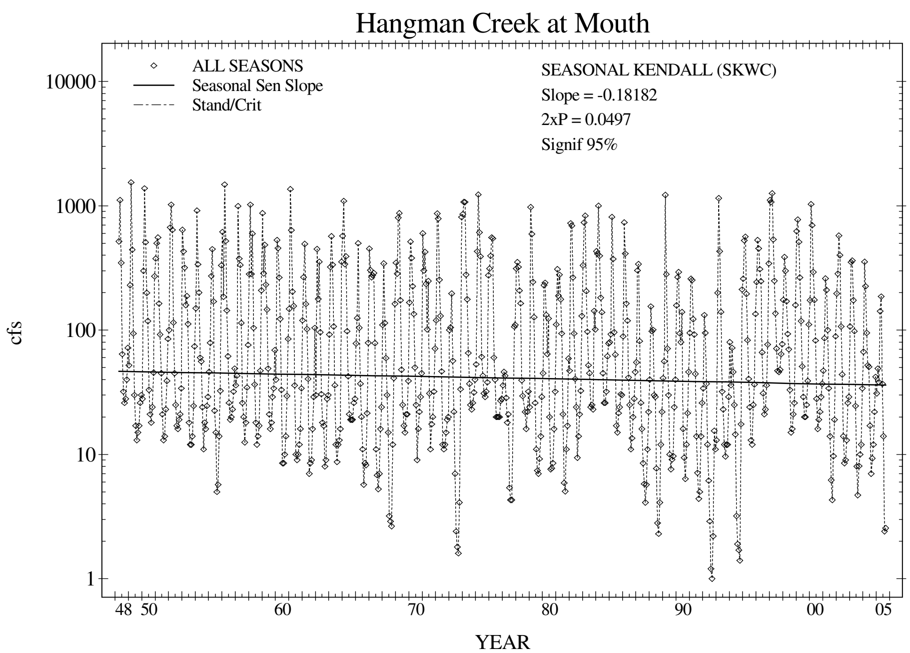

Figure 7. A Seasonal Kendall trend analysis of monthly median flows for Hangman Creek at the USGS station (12424000).

For TMDL comparison purposes, 1995 and 2004 water years had the most water quality data for the watershed. Water year 2001 is of interest because it is the critical low-flow year designated for the draft *Spokane River Dissolved Oxygen TMDL* (Ecology, 2007). Phosphorus loads from Hangman Creek are expected to meet load allocations set by the *Spokane River Dissolved Oxygen TMDL* during future critical low-flow years (Ecology, 2007). Phosphorus loads are very closely correlated with discharge volumes and suspended sediment loads in the Hangman watershed.

These three water years, 1995, 2001, and 2004, are representative of very diverse flow conditions. In Table 12, the mean annual flow in 1995 was double the 2004 flow and three times the 2001 flow. The 1995 water year also had 48 days with mean daily flows over the 10% flow exceeds statistic (567 cfs). This was three times the number of days in 2004 and six times the number of days in 2001.

Table 12. Monthly and annual daily mean flow statistics (cfs) and the number of days in the water year when mean discharge exceeded 567 cfs, the 10% flow exceeds statistic (Kimbrough et al., 2006).

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Daily Mean	Days >567
1994	11	12.1	34.8	93.6	39.5	86.6	56.2	28.5	13.8	4.11	1.96	1.71	32.1	0
1995	2.39	21.8	405.7	590.5	960.2	670.2	194.7	77.7	41.5	22.7	12.3	12.7	247.2	48
1996	25.3	40.8	270.9	482.7	1,776	735.2	628.4	298.4	79.8	34.4	21.5	22.6	362.2	49
1997	41.8	215.9	888.8	2,097	1,376	1,616	664	364.8	143.5	73.8	47.3	46.2	629.1	111
1998	48.5	75.6	96	465.2	431.9	348.7	171.9	218.2	93.3	31.4	15.5	15.7	166.3	23
1999	20.1	37.9	529.9	755.4	1,302	677.2	266.7	126.3	56.2	29.5	20.6	19.8	314.6	52
2000	26	47.1	221.5	242.3	1,254	739.8	454	182.3	87.8	31.2	16.3	18.5	272.8	55
2001	23.4	29.5	36.7	48.1	123	328.7	209.5	150	31.3	15.4	6.36	4.36	83.7	8
2002	9.25	25.5	220.9	534.3	625.4	761.5	397.6	116.5	46.5	15.5	8.62	9.76	228.9	37
2003	13.4	22.9	31.5	230.9	477.7	561.1	195	106.6	29.9	7.93	4.88	7.34	138.8	19
2004	9.31	12.1	35.5	226.9	558	273.7	94	203.9	60.7	17.5	6.71	8.85	124.1	16
2005	14.7	23.5	58.5	142.1	50.6	157.1	161.5	208.4	42.9	13.8	2.53	2.68	73.5	6

In the 2004 water year, the estimated average annual discharge for Hangman Creek at Tekoa was approximately 69.5 cfs, or 56% of the mouth (Figure 8). The Coeur d'Alene Reservation and Idaho portions of the mainstem Hangman Creek upstream of the gaging site comprise 19.5% of the basin area. The annual average discharge at Duncan (RM 19.9) just below the confluence of Rock Creek was 103 cfs, or 83% of the mouth that included 80% of the basin area.

In 1995, there was not a continuously recording gage at the Idaho border. However, based on regressions of paired instantaneous measurements, the average daily discharge at the Idaho border in 1995 was estimated to be 82 cfs. That flow would mean a 33% contribution from the upper watershed to the streamflow volume leaving Hangman Creek. Most likely the greater snow pack, lower temperatures, and higher rainfall increased the apparent contribution from the lower watershed compared to 2004.

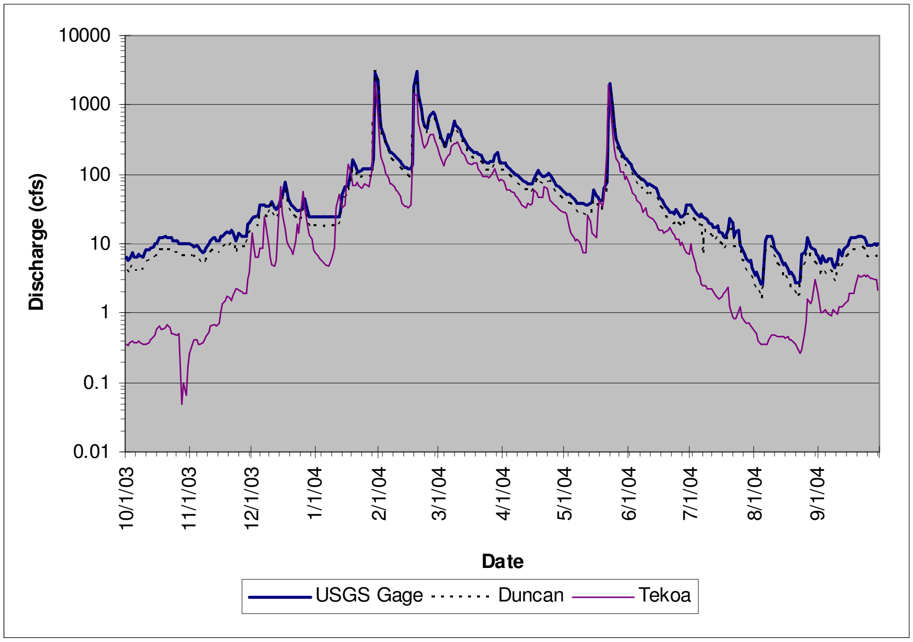

Figure 8. Comparisons of average daily discharge along Hangman Creek at Tekoa river mile (RM) 54.6, Duncan Road at RM 19.9, and the USGS gage at RM 0.8 for water year 2004.

Portions of Rock Creek are also in the Coeur d'Alene Reservation. The streamflow contribution to Rock Creek from these areas has not been evaluated. Together the Rock Creek, Little Hangman Creek, and the upper mainstem areas in the Coeur d'Alene Reservation and Idaho comprise about 35% of the watershed area. However, the total streamflow contribution across the border to Hangman Creek may be more substantial since Hangman Creek above Tekoa can contribute 56% in some years.

Climate

Air temperatures and precipitation during the three water years were also very different from one another. In 1995, maximum monthly average temperatures were higher than normal in fall and winter, but lower than normal in the summer (Figure 9). In contrast, 2001 had lower than normal temperatures in fall and winter and higher temperatures at the end of summer. Maximum monthly average temperatures in 2004 were near normal except for a warm early spring. Precipitation volumes were higher than average in 1995, lower than average in 2001, and about average in 2004 (Figure 10).

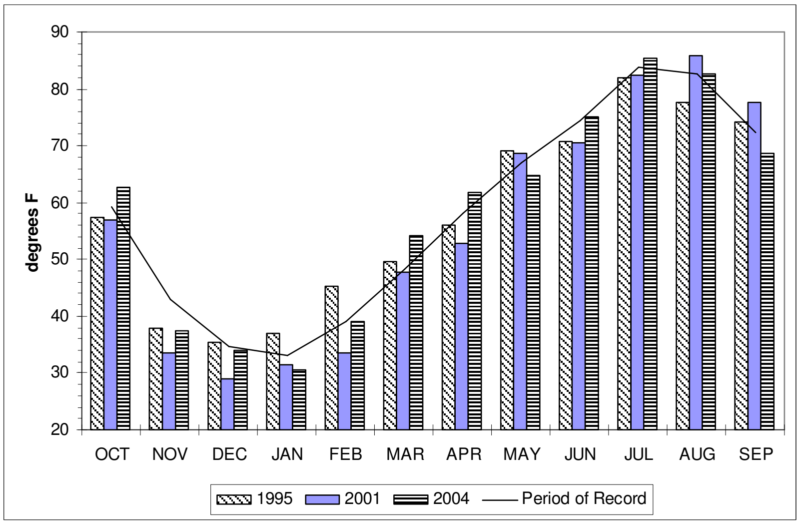

Figure 9. A comparison of long-term average (Period of Record) monthly maximum temperatures to those in water years 1995, 2001, and 2004 at the Spokane Airport (Western Regional Climate Center, 2006).

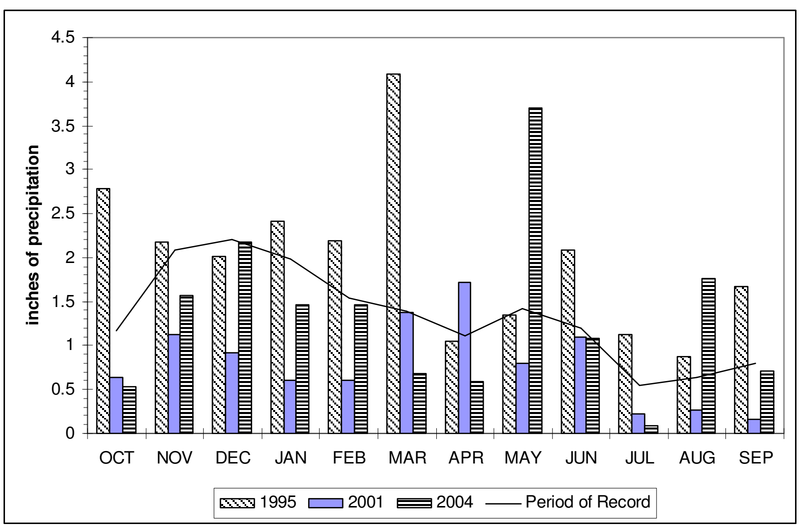

Figure 10. A comparison of long-term average (Period of Record) monthly rainfall volumes to volumes in water years 1995, 2001, and 2004 at the Spokane Airport (Western Regional Climate Center, 2006).

Climate and river flow records are less complete in the upper watershed in Idaho. The climate records in Plummer and Tensed, Idaho follow the patterns of the Spokane Airport for the months and years they are available (Western Regional Climate Center, 2006). Both Plummer and Tensed tend to have lower maximum monthly temperatures and more rainfall than Spokane because of their higher altitude (approximately 200' to 300') with resulting orographic effects.

TMDL Analyses

Fecal coliform

Areas of concern

Fecal coliform (FC) criteria violations have been documented at the mouth of Hangman Creek since the 1970s (Ecology, 2006). The Ecology ambient monitoring site (56A070) is sampled monthly and has provided a long-term record of the bacterial quality of the creek. The monthly FC counts have varied widely over a particular water year and from year to year. As with most water quality data, long-term annual trends and seasonal trends change somewhat with the period of record chosen to analyze.

The trends over the past 10 years (1995–2005) of FC counts, flows, and calculated FC loads are shown in Figures 11–13. The FC counts at the mouth continue to periodically exceed the FC criterion, but there has not been a significant trend. The monthly discharge (Figure 12) has shown a significant decreasing trend that has influenced the FC load trend (Figure 13). This implies that flow is not necessarily the most dominant factor on FC counts.

FC counts at the mouth of Hangman Creek are especially relevant to recreational uses and human health because of easy public access through the city park located at the confluence of Hangman Creek and the Spokane River. Elevated counts also could affect downstream public access areas on the Spokane River. Based on the monitoring data, this site is on the 303(d) list for not supporting recreation uses.

As previously shown in Tables 1, 2 and 3, Spokane County Conservation District (SCCD) monitoring studies (SCCD, 1999; 2000) have documented other reaches of Hangman Creek with FC criteria violations as well:

- Hangman Creek at Bradshaw Road (RM 32.9)
- Rock Creek at Jackson Road
- Little Hangman Creek
- Hangman Creek at the border with Idaho (RM 54.3)
- Tributary to Hangman Creek at Griffith Road

The Tekoa Wastewater Treatment Plant (WWTP) study by Carey (1989) also identified reaches below Tekoa (RM 53.5) which have remained on the 303(d) list from the 1990s to the present.

The most recent monitoring study conducted by the SCCD identified more reaches of the mainstem Hangman Creek with suspected FC criteria violations (SCCD, 2005a):

- Spring Valley Road
- Marsh Road
- Roberts Road
- Keevy Road
- Latah Creek Road at river mile 21.4
- Duncan Road

All sites had FC values not meeting criteria over the 2003–2004 survey period (Table 13). When all samples of the survey were used for the statistical analysis, all of the sites met the geometric mean criteria except Keevy Road, but most had 10% of their values, or the 90th percentile of the values, greater than the 200 count/100 mL criterion. The Keevy Road site was sampled only five times during the study, so the statistics are not as representative as for most other sites.

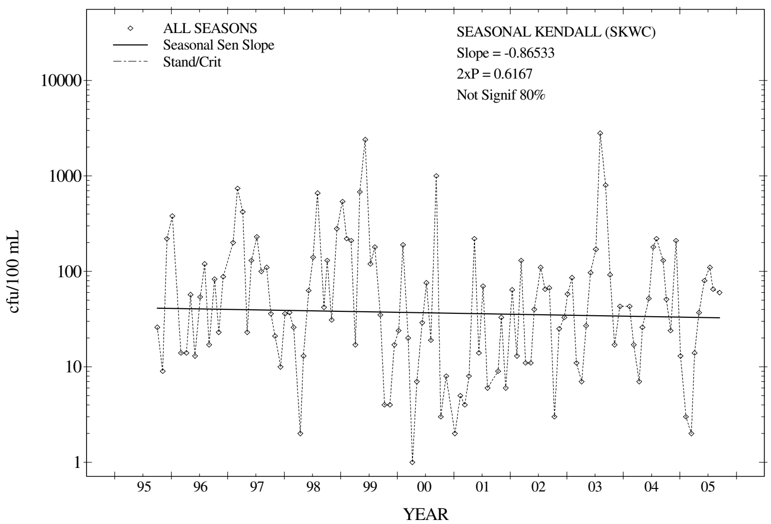

Figure 11. Trend of FC counts (concentration) in samples collected from Hangman Creek by Ecology at site 56A070, 1995-2005.

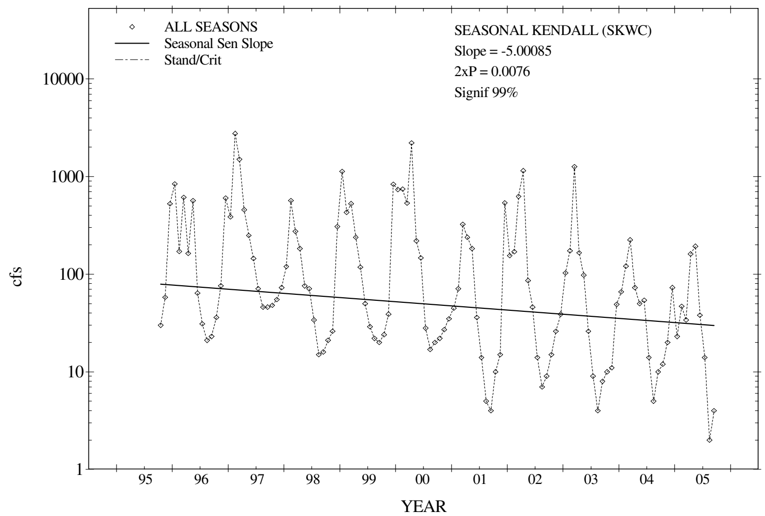

Figure 12. USGS discharge trend on Hangman Creek at mouth (12424000), 1995–2005.

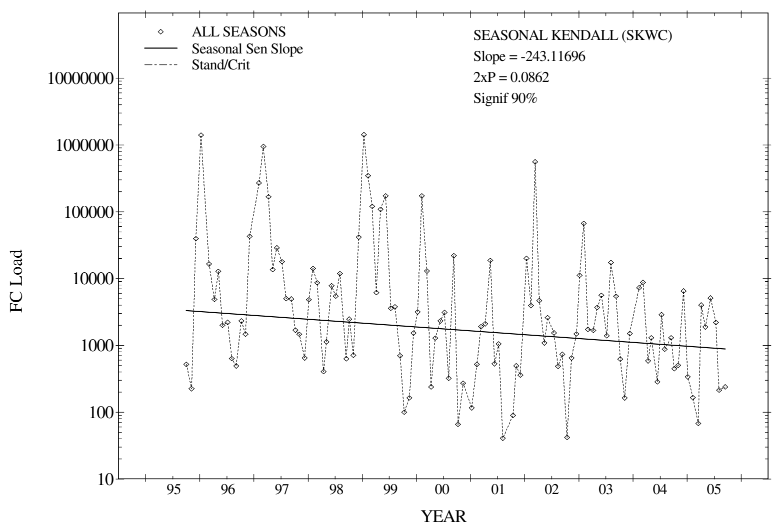

Figure 13. FC load (instantaneous streamflow in cfs x coliform count in cfu/100 mL) trend on Hangman Creek at the mouth (56A070), 1995–2005.

Table 13. A statistical summary of all fecal coliform bacteria results from samples collected by the Spokane County Conservation District in the Hangman Creek watershed from December 2003 to August 2004.

Map ID	Site	No. of Samples	Geo. Mean	90th %tile	> 200	Average Load
			cfu/ 100 mL	cfu/ 100 mL		cfu/day x 10^{10}
1	Hangman Creek at State Line (Rd)	11	64	**505**	**27%**	120
2	Hangman Creek at Fairbanks Rd	7	46	**454**	**29%**	54
12	Cove Creek	11	84	**1003**	**45%**	0.6
4	Hangman Creek at S. Valley Rd	7	68	**567**	**29%**	80
3	Hangman Creek at Marsh Rd	7	33	**334**	**14%**	49
6	Hangman Creek at Roberts Rd	11	40	**316**	**18%**	70
5	Hangman Creek at Chapman Rd	7	64	**227**	**14%**	45
21	Hangman Creek at Keevy Rd	5	**173**	**4670**	**60%**	170
7	Hangman Creek at River Mile 21.4 on Latah Creek Rd	11	55	**520**	**27%**	67
14	Rock Creek at mouth	11	94	**509**	**27%**	22
13	Rock Creek at Rockford	11	36	**609**	**27%**	7.4
17	Spangle Creek	7	25	**276**	**14%**	0.12
8	Hangman Creek at Duncan Rd	11	36	**247**	9%	78
16	California Creek at mouth	11	15	178	9%	0.32
15	California Creek at Marsh Rd	11	28	**390**	**18%**	0.14
19	Marshall Creek at mouth	11	30	**204**	9%	0.18
18	Marshall Creek at McKenzie Rd	11	9	113	9%	0.3
11	Hangman Creek at USGS gage*	19	49	**439**	**18%**	47

*Includes samples collected by Ecology at the co-located long-term monitoring site 55A070.
FC counts not in compliance with state FC criteria are indicated with bold type. Map identification refers to Figures 5 and 6.

Tributaries also were not in compliance with FC criteria at sites on Cove Creek, Rock Creek, Spangle Creek, upper California Creek, and lower Marshall Creek (Table 13). These join Little Hangman Creek and Rattler Run on the list of tributaries that require further work (Table 2). Of the monitored tributaries, only upper Marshall Creek and lower California Creek met state criteria during the 2003-2004 TMDL survey period.

The discharge monitoring reports (DMRs) from 2002-2005 for the wastewater treatment plants (WWTPs) in the watershed were reviewed as part of the TMDL study. All of the permits, except for the Tekoa WWTP, have FC limits more stringent than for best conventional technology. The WWTP data from the DMRs imply that some WWTPs have had FC disinfection problems in the recent past. Effluent FC concentrations at Fairfield and Tekoa were out of NPDES permit compliance for several months in 2004 and 2005 (Table 14). A more recent review of DMRs suggests that these disinfection problems have since been corrected.

Considering the low dilution factor for the Tekoa WWTP, Hangman Creek may not be adequately protected below the outfall under the current permits. For example, repeated effluent FC counts between 200 cfu/100 mL and 400 cfu/100 mL would comply with NPDES permit limits, but could raise counts downstream above the *Primary Contact* criteria during low-flow periods. Limiting Tekoa WWTP effluent FC counts to a monthly geometric mean of 100 cfu/100 mL and a weekly geometric mean of 200 cfu/100 mL would ensure downstream criteria are met.

Stormwater runoff is also a source of concern for FC loading to Hangman Creek and its tributaries. Fecal loading from stormwater sources could not be specifically identified in this study. The stormwater permit monitoring requirements for WSDOT, the City of Spokane, and Spokane County were not in effect when the monitoring program was designed. Urbanized areas, Highway 195, and Interstate 90 are located in the lower Hangman Creek where increases in FC loading were observed during the 2003–2004 TMDL surveys. Future bacteria load characterization of stormwater sources may be necessary.

In summary, more comprehensive watershed sampling in 2003 and 2004 has shown that most areas of the mainstem of Hangman Creek and many tributaries have FC problems. On the other hand, few sites appear to have chronic FC violations. The FC problems may have been worse in the past. Although low-flow conditions at the mouth of Hangman Creek can result in high FC counts, storm events at any time of the year can cause many sites to violate state criteria. Some WWTPs had FC disinfection problems that required attention and have been corrected.

Table 14. Fecal coliform NPDES permit limits and the number of times limits were exceeded at six wastewater treatment plants in the Hangman Creek watershed.

WWTP	Average Monthly Permit		Average Weekly Permit		Data Record Reviewed
	Limit	# Exceed	Limit	# Exceed	Dates
Cheney	50	1[1]	100	3[1]	Jan 2003 – Dec 2005
Fairfield	100	5	200	7[2]	Dec 2004 – Dec 2005
Freeman School District	100	1	100	3	Jan 2003 – Dec 2005
Rockford	100	1	200	2	Jan 2003 – Dec 2005
Tekoa	200	4	400	9	Dec 2002 – Dec 2005
Spangle	100	0	200	1	Jan 2003 – Dec 2005

[1] Fecal coliform counts discharged to the wetland treatment system, not to the tributary of Minnie Creek.
[2] Exceedances occurred during newly installed equipment startup conditions. More recent review of data suggests disinfection problems have been corrected.

Critical conditions

A long-term (1989–2004) evaluation of flow conditions when FC criteria violations occur at the mouth of Hangman Creek is shown in Figure 14. The FC loads for individual monthly samples collected at Ecology site 56A070 are compared to FC loads compliant with the 100 cfu/100 mL and 200 cfu/100 mL criteria along a frequency flow graph. November to May FC violations tend to occur when flows are greater than 571 cfs, or less than 10% of the time on a long-term discharge basis. June to October violations appear to be evenly distributed along the lower half of the frequency curve.

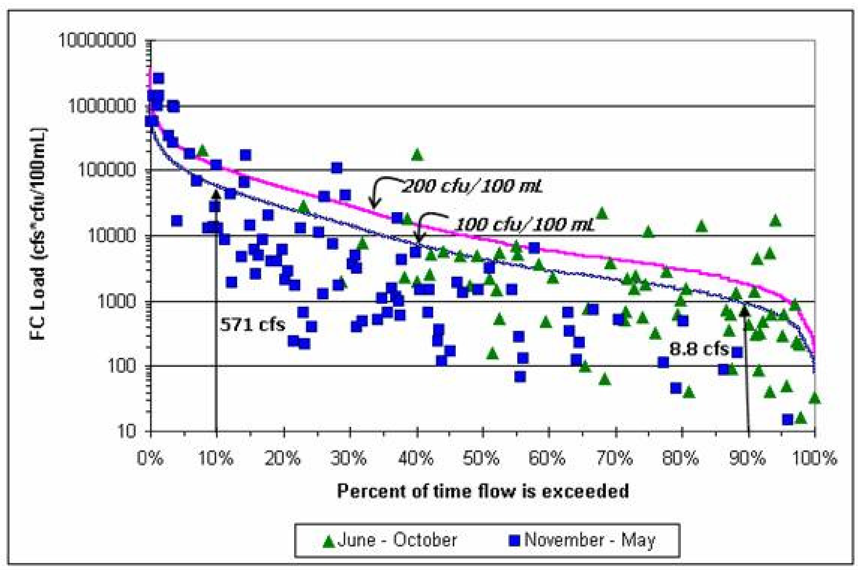

Figure 14. Seasonally-stratified fecal coliform loads calculated from data collected from 1989 to 2004 at the mouth of Hangman Creek (Ecology site 56A070).

Loads are compared to criteria-compliant fecal coliform loads (solid lines) along a frequency curve for daily average flows from 1948 to 2004.

Sources creating these violations under different flow conditions have not been specifically identified in the watershed. Several reaches in the watershed have direct access to water or riparian areas for herds of cattle, horses, or other livestock. Wildlife and waterfowl frequent the stream corridors as well. These can be direct sources of fecal contamination along with inadequate septic systems and poorly disinfected wastewater, especially apparent during the low-flow period.

Often sources of FC contamination accumulate loads on land or along riparian corridors until a storm event can wash them into the creek. The 'first flush' mechanism is well documented in urban stormwater situations where feral and domestic animals can be major contributors to bacterial contamination. Another mechanism during storm events may be FC organisms from earlier sources that are adsorbed to sediment, settle to the bottom of the creek, and then resuspended as flows and water velocities increase. According to research, FC can remain viable in sediments for months under favorable conditions (Sherer et al., 1992).

In 2003 and 2004, the elevated 90th percentile values at most sites were usually the result of targeted storm events. The storm events that were monitored in 2003 and 2004 occurred in the winter and in the summer (SCCD, 2005a). Although this appears to be contrary to the relationship just shown between flows and FC counts with long-term trends, historical data suggest that elevated FC counts have occurred during storm runoff periods throughout the period of record at the mouth of Hangman Creek.

In 2003-2004, Rock Creek, Cove Creek, Spangle Creek, upper California Creek, and Hangman Creek at Keevy Road and at River Mile 21.4 had elevated FC counts occurring at times other than storm events. Earlier work by the SCCD (1999; 2000) had similar findings. The elevated counts at these sites suggest either a fixed source or nonpoint sources other than surface run-off from properties adjacent to the stream network (e.g., access by wildlife or livestock, pet waste dumping, or malfunctioning on-site or public sewage systems.

A simple estimate of average FC loads with and without the storm event data suggests that storm events may have been responsible for over 90% of the FC loading in the mainstem at the Idaho border. The percentage attributed to storm event loads at the mouth of Hangman Creek was about 70%. In most tributaries, the range was 20% - 60%. The mouth of Rock Creek had only 14% of the estimated average FC load attributed to the storm events.

Researchers have found that storm events are often responsible for the majority of the annual pollutant load in a watershed. In a drier than normal water year such as 2004, the influence of the few storm events may be exaggerated compared to average conditions in the watershed. Estimates on higher flow years, like the 1995-1997 FC data, suggest that storm events were less influential on the annual FC loads in Hangman and Rock Creeks.

Considering the likelihood of storms at any time of year and the paucity of data for many sites, no seasonal critical condition for FC has been established for most sites in the watershed, so all available data were used. Data for Hangman Creek at State Line (Road) and Hangman Creek at the mouth were numerous enough to evaluate by season, and loading capacities were developed on the most critical months for chronic FC criteria violations:

- Hangman Creek at State Line (Road) August – January
- Hangman Creek at the mouth July – September

The months used for the critical condition at these two sites somewhat followed the relative influence of stormwater and low streamflows on FC counts. FC counts at the mouth appear to be less dominated by storm runoff, so drier months with lower streamflows are critical. The site at the Idaho border appeared to have equally elevated FC counts during both low flow (August–October) and from storm runoff (November–January).

Analytical framework

The FC evaluation is approached conservatively to account for its wide daily and seasonal variability. All of the FC sample counts from a site are tested for their statistical distribution characteristics. Most follow a lognormal distribution, so the following assumptions are made with reference to water quality criteria:

- The geometric mean of the samples is equal to the transformed mean of the lognormal distribution.
- The transformed 90th percentile of the lognormal distribution is equal to the value that not more than 10% of the counts should exceed.

In most cases, these assumptions are more conservative for designating the 90th percentile or 'not more than 10% of the values to exceed'. The variability of the distribution is considered in calculating the 90th percentile. However, statistics based on 10 or fewer samples should be viewed with greater caution since all types of conditions may not be represented.

The Statistical Rollback Method (Ott, 1995) was used to determine if the FC distribution statistics for individual sites meet the water quality criteria in the Hangman Creek watershed. The method has been successfully applied by Ecology in other FC bacteria TMDL evaluations (Cusimano and Giglio, 1995; Joy, 2000; Coots, 2002; Joy and Swanson, 2005).

The method is applied as follows:

The geometric mean (approximately the median of the lognormal distribution) and 90th percentile statistics are calculated and compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the most restrictive of the two criteria. The 90th percentile criterion is usually the most restrictive. So rolling-back means maintaining the slope of the original lognormal FC data distribution with the 90th percentile of the distribution set at 200 cfu/100 mL.

The rolled-back geometric mean and 90th percentile FC value then define the "target" FC distribution for the site. (The term target is used to distinguish these estimated numbers from the actual water quality criteria.) The amount a distribution of FC counts is "rolled-back" to the target values is the estimated percent of FC reduction required to meet the FC water quality criteria and *contact recreation* water quality standards. A detailed graphical example is shown in Appendix C.

The rollback was applied to the most representative distribution after taking several analytical steps. At sites with historical data, both step trends and monotonic trend analyses were performed on FC counts and streamflows to determine the most recent and stable dataset(i.e., to ensure that high water and drought years are represented equally). Trend analyses, tests for seasonality and statistical tests for lognormal distributions were performed using WQHYDRO, a statistical software package for environmental data analysis (Aroner, 2007). The geometric mean and 90th percentile statistics for various subsets of data were then calculated and compared to determine a critical season at each site and to calculate the target TMDL values.

It is important to remember that the FC TMDL targets based on the statistical rollback are only in place to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is measured as meeting water quality criteria. Any waterbody with FC TMDL targets is expected to meet both of the applicable geometric mean and 'not more than 10% of the samples' criteria and meet beneficial uses for the category.

A Beales ratio estimator formula (Dolan et al., 1981) was used to calculate the annual FC loads at sites with adequate pollutant and streamflow data (Appendix C). The Beales formula provides a better annual or seasonal estimate of pollutant loads compared to the average instantaneous load obtained from a few sampling events. The average instantaneous load was calculated when continuous discharge data were absent or could not be estimated from nearby gauging data.

Fecal coliform load model comparisons

We also compared the FC load estimates at the mouth of Hangman Creek using three methods. We compared the results from the Beales formula, a simplified monthly mass loading calculation, and a multiple regression model (Cohn, 1988). Comparing the results from the three methods provided an estimate of the FC load variability.

The three methods of calculating FC loads at the mouth of Hangman Creek came into fairly close agreement for most months (Figure 15). The Beales and simple average monthly loads were more similar to each other than to the Cohn multiple regression model results. Average monthly FC load estimates were most similar during the low-flow periods. As may have been expected, variable streamflow during the fall and spring months resulted in wider divergence of FC loads.

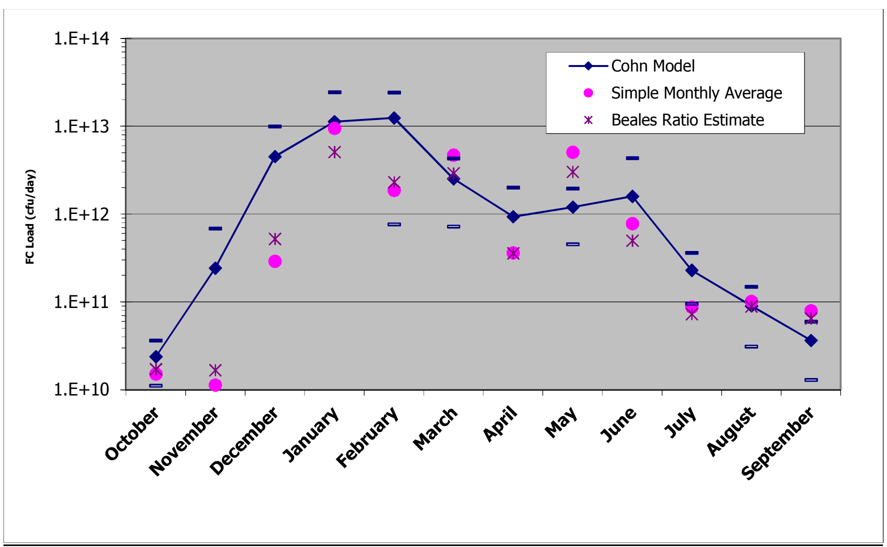

Figure 15. A comparison of monthly fecal coliform average loads at the mouth of Hangman Creek from October 1989 to September 2005 (Ecology site 56A070).

The critical season for FC criteria violations at the mouth of Hangman Creek is July through September. FC loads are not at their peak at that time, but setting reduction targets to water quality standards should reduce FC loads during higher flows if source controls are implemented. Figure 16 illustrates the anticipated effect on the FC distribution at the mouth of Hangman Creek (Figure 14) after implementing FC source reductions by 72% estimated by the roll-back method. The reductions may be most successful at higher flows, but FC violations at lower flows will also be reduced to acceptable levels.

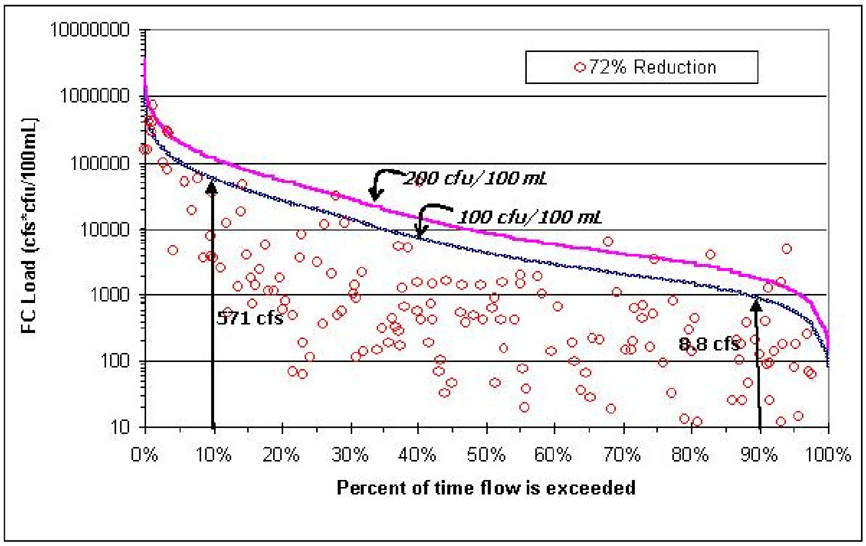

Figure 16. Application of a 72% reduction in fecal coliform loading sources to data previously collected at the mouth of Hangman Creek to demonstrate its anticipated effectiveness.

Loading capacity

Definition and determination

EPA regulations define loading capacity as the greatest amount of pollutant loading that a waterbody can receive without violating water quality standards [40CFR§130.2(f)]. The loading must be expressed as mass-per-time or other appropriate measure. Also, the critical conditions that cause water quality standard violations must be considered when determining the loading capacity.

Washington State FC bacteria TMDLs use a combination of mass-per-time units and statistical targets to define loading capacities. This is necessary since mass-per-time units (loads) do not adequately define periods of FC criteria violations. Loads are instructive for identifying changes in FC source intensity between sites along a river, or between seasons at a site. However, FC sources are quite variable. Different sources can cause FC criteria violations under different loading scenarios (e.g., poor dilution of contaminated sources during low-streamflow conditions or increased source loading during run-off events).

The statistical targets provide a better measure of the loading capacity during the most critical period. The FC loading capacity at Hangman Creek watershed sites is based on the applicable two statistics in the state FC criteria (e.g., the geometric mean and the value not to be exceeded by more than 10% of the samples). As discussed earlier in the *Analytical Framework* section, the 90th percentile value of samples is used in TMDL evaluations for the latter criteria statistic. The FC TMDL target loading capacities in the following table are either the criteria, or they are statistics that estimate the reductions necessary to meet the criteria (Table 15).

Table 15. The loading capacities and target fecal coliform statistics for Hangman Creek watershed sites. Map ID refers to Figures 5 and 6.

Map ID	River Mile	Location	Critical Period*	No. Samples	FC Reduction	FC Target Capacity (cfu/100 mL)	
						90th % tile	Geomean
1	57.4	Hangman Creek at State Line (Rd)	Aug - Jan	20	72%	200	36
2	50.4	Hangman Creek at Fairbanks Rd	Annual	7	56%	200	20
4	47.0	Hangman Creek at Spring Valley Rd	Annual	7	65%	200	24
3	47.3	Hangman Creek at Marsh Rd	Annual	8	32%	200	24
6	41.5	Hangman Creek at Roberts Rd	Annual	12	27%	200	36
13	32.9	Hangman Creek at Bradshaw Rd	Annual	35	60%	200	30
21	29.2	Hangman Creek at Keevy Rd	Annual	12	78%	200	11
7	21.4	Hangman Creek at river mile 21.4	Annual	12	56%	200	20
8	18.6	Hangman Creek at Duncan Rd	Annual	12	10%	200	27
11	0.8	Hangman Creek at mouth	July - Sept	43	72%	200	40
--		Little Hangman Creek at Tekoa	Annual	21	67%	200	31
12		Cove Creek	Annual	12	79%	200	19
--		Unnamed Tributary at Griffith Rd	Nov-May	7	25%	200	22
--		Unnamed Tributary at Roberts Rd	Jun-Oct	7	61%	200	19
--		Rattler Run	Annual	31	85%	200	12
13		Rock Creek at Rockford	Annual	11	67%	200	12
--		Rock Creek at Jackson Rd	Annual	33	68%	200	16
14		Rock Creek at Mouth	Annual	12	70%	200	34
17		Spangle Creek	Annual	7	28%	200	18
15		California Creek at Marsh Rd	Annual	12	49%	200	14
16		California Creek at Mouth	Annual	12	23%	200	15
18		Marshall Creek at McKenzie Rd	--	11	--	200	9
19		Marshall Creek at the mouth	Annual	12	54%	200	19

The percentage reduction values in Table 15 indicates the relative degree the waterbody is out of compliance with criteria (i.e., how far it is over its capacity to receive FC source loads and still provide the designated beneficial uses). Marshall Creek at McKenzie Road currently meets the loading capacity and does not have a FC reduction value. Sites that require aggressive reductions in FC sources will have a high FC percentage reduction value (greater than 60%), while sites with minor problems will have a low FC percentage reduction value (less than 30%). As previously mentioned, statistics based on less than 10 samples should be viewed with caution since not all conditions were monitored.

Since the loading capacity and statistical values are based on the critical condition, Table 15 includes the critical period. The reductions do apply to the entire year, but the more stringent TMDL reduction protects water quality for the most critical season. If the critical period is annual, no seasonal changes were noted in the available data and the entire record was used. The critical season provides water quality managers and local citizens a sense of what type of FC sources may require the most work.

The previous discussions and evaluations of the fecal coliform data showed that storm events were important drivers of criteria violations at many sites in the watershed, especially during the 2004 TMDL monitoring period. Sites with limited data have load capacity targets most heavily influenced by the storm event data. The recommended targets and reductions are probably more restrictive than they would be if more data were collected over a wider range of climatic and hydrologic conditions.

Figure 16 results suggest that when the requirement is as high as 72%, FC counts are reduced under all flow and seasonal conditions. However, the effectiveness of reductions will depend on the actions taken on a variety of sources. For example, the 72% reduction could be effective throughout the year if livestock are kept well away from direct water access and riparian areas. Summer FC counts would respond to direct contact, and storm event counts would respond to manure washed from riparian areas and resuspended from streambeds. Septic system improvements would probably only change summer counts unless there is inundation from flood waters.

Load and wasteload allocations

This TMDL technical evaluation of the Hangman Creek watershed demonstrated that contact recreation is impaired in most areas that were investigated and that FC load reductions are necessary. The estimated load allocations and wasteload allocations are shown in Table 16. Most of the FC load sources are nonpoint in nature and require load allocations. The point sources in the basin are assigned wasteload allocations based on their weekly average NPDES permit limits, or on adjusted permit limits if water quality based limits are necessary.

Table 16. Fecal coliform load allocations and wasteload allocations for sites and point sources in the Hangman Creek watershed. Stormwater loads were not calculated (NC).

Hangman Creek Reach, Point Source, or Tributary	Listing ID	WLA or LA (cfu/day)	Current Load (cfu/day)	Target Reduction (%)	Target Basis WLA/LA WQ criterion
Hangman Creek at State Line (Rd)[+]	41992	5.6×10^{11}	2.0×10^{12}	72%	10% < 200
Little Hangman Creek	41994	5.6×10^{10}	1.7×10^{11}	67%	10% < 200
Tekoa WWTP		3.1×10^{9}	1.4×10^{10}	78%	Weekly< 200[1]
Hangman Creek at RM 53.8	6726	6.2×10^{11}	2.2×10^{12}	72%	10% < 200
Hangman Creek at Fairbanks Road	46497	2.4×10^{11}	5.4×10^{11}	56%	10% < 200
Hangman Creek at Spring Valley	46493	2.8×10^{11}	8.0×10^{11}	65%	10% < 200
Hangman Creek at Marsh Road	45306	3.3×10^{11}	4.9×10^{11}	32%	10% < 200
Cove Creek	45629	1.3×10^{9}	6.0×10^{9}	79%	10% < 200
Unnamed tributary at Griffith Road	45553	3.0×10^{8}	4.1×10^{8}	25%	10% < 200
Unnamed tributary at Roberts Road	45110	1.5×10^{8}	3.0×10^{8}	61%	10% < 200
Hangman Creek at Roberts Road	45242	5.1×10^{11}	7.0×10^{11}	27%	10% < 200
Hangman Creek at Bradshaw Road	16863	6.8×10^{11}	1.7×10^{12}	60%	10% < 200
Rattler Run at mouth	45310	2.3×10^{9}	1.5×10^{10}	85%	10% < 200
Rattler Run Nonpoint	--	0.5×10^{9}	6.0×10^{9}	92%	10% < 200
Fairfield WWTP	--	1.8×10^{9}	9.0×10^{9}	80%[2]	Weekly< 200
Hangman Creek at Keevy Road	45268	3.7×10^{11}	1.7×10^{12}	78%	10% < 200
Hangman Creek at river mile 21.4	45250	2.9×10^{11}	6.7×10^{11}	56%	10% < 200
Rock Creek at mouth	45312	6.6×10^{10}	2.2×10^{11}	70%	10% < 200
Rock Creek at Jackson Road	41996	2.4×10^{11}	7.5×10^{11}	68%	10% < 200
Rockford WWTP	--	2.0×10^{9}	4.7×10^{9}	57%[2]	Weekly< 200
Freeman School District WWTP	--	1.6×10^{8}	1.9×10^{8}	16%	Weekly< 100
Rock Creek at Rockford[+]	46317	2.4×10^{10}	7.4×10^{10}	67%	10% < 200
Spangle Creek at mouth	45347	8.6×10^{8}	1.2×10^{9}	28%	10% < 200
Spangle Creek Nonpoint Sources	--	2.0×10^{8}	1.0×10^{9}	80%	10% < 200
Spangle WWTP	--	6.6×10^{8}	2.2×10^{8}	Weekly< 200	
Hangman Creek at Duncan Road	45251	7.0×10^{11}	7.8×10^{11}	10%	10% < 200
California Creek at mouth	41991	2.5×10^{9}	3.2×10^{9}	23%	10% < 200
California Creek at Marsh Road	46287	7.1×10^{8}	1.4×10^{9}	49%	10% < 200
WA State Dept. of Transportation	--	NC	NC	72%	10% < 200
Spokane(City& County) stormwater	--	NC	NC	72%	10% < 200
Marshall Creek at mouth	41995	8.3×10^{8}	1.8×10^{9}	54%	10% < 200
Marshall Creek at McKenzie	46270	3.0×10^{9}	3.0×10^{9}	no reduction required	
Cheney WWTP*	--	1.0×10^{10}	–	Weekly< 100*	
City of Spokane stormwater WLA	--	NC	NC	72%	10% < 200
Hangman Creek at mouth	45260	2.3×10^{10}	8.2×10^{10}	72%	10% < 200

WLA = wasteload allocation.
LA= load allocation.
+ Assumes reductions from Hangman Creek from the Coeur d'Alene Tribe Reservation and State of Idaho.
* Cheney WWTP WLA based on effluent FC count to the wetland being the same if discharged to Minnie Creek.
[1] Based on more stringent Tekoa WWTP FC permit limits: monthly geometric mean of 100 cfu/100 mL and a weekly geometric mean of 200 cfu/100 mL.
[2] Based on reviews of 2003-2005 WWTP DMRs. More recent DMRs suggest these WWTPs are currently meeting concentrations protective of bacteria water quality standards.

Monitoring sites along Hangman Creek and on tributaries in the watershed become points for load allocations. Unless point sources with wasteload allocations are present upstream, nonpoint source load allocations and required levels of reduction assume that FC sources are nonpoint in nature. Nonpoint sources are often difficult to separate from background sources such as wildlife and waterfowl. No attempt with this dataset has been made to allocate FC loads separately to background sources. For example, beaver activity at the mouth of Cove Creek may be taking all of the load allocations for lower Cove Creek. This will not be known until more intensive monitoring is conducted upstream.

Point sources were evaluated based on monitoring reports from 2002-2005. Since this time, some changes have taken place to improve disinfection procedures and reduce the frequency of permit violations. The Ecology permit managers and WWTP operators should continue to work together to ensure consistent disinfection and meet current permit limits. Except for Tekoa none of the permits appeared to require more stringent limits to achieve instream FC criteria. Limiting Tekoa WWTP effluent FC counts to a monthly geometric mean of 100 cfu/100 mL and a weekly geometric mean of 200 cfu/100 mL would ensure downstream criteria are met during low-flow conditions. The Cheney WWTP limits are based on FC counts to the wetland since effluent from the wetland has not discharged to Minnie Creek via the surface outfall.

Fecal coliform stormwater loads in urban areas are considered capable of occurring at any time. Therefore, municipal stormwater FC wasteload allocations were not specifically reserved for a 'storm' season. Although not specifically investigated or given a specific load in this study, the stormwater FC reductions are assigned in Table 16 until better data can be obtained. They are based on the FC reductions (72%) necessary to achieve water quality standards in lower Hangman Creek during the critical period.

WSDOT, the City of Spokane, and Spokane County are jurisdictions with Phase 2 stormwater permits. These jurisdictions are expected to locate and evaluate outfalls within the area covered by the NPDES permit. If necessary, they will work with Ecology permit managers to maintain or upgrade BMPs to reduce FC loading to the Hangman Creek watershed.

Hangman Creek, Little Hangman Creek, and Rock Creek will require FC load reductions coming across the Idaho border into Washington. Ecology encourages the EPA, the Coeur d'Alene Tribe, and the State of Idaho to work together to reduce the upstream FC loads.

Conclusions and recommendations

The following conclusions and recommendations are based on this fecal coliform TMDL evaluation:

Conclusions

- Fecal coliform loads at the mouth of Hangman Creek appear to be decreasing over the long-term, but this may be a result of declining streamflows rather than declining fecal coliform counts.

- Fecal coliform (FC) counts do not meet Washington State criteria at several locations in the watershed, but no location appeared to be chronically degraded.
- Storm events at any time of the year result in elevated FC counts in many reaches of the watershed, and are the main cause of criteria violations that require TMDL load reductions.
- The sources of FC contamination in the watershed are not obvious, but may include livestock riparian access, malfunctioning on-site septic systems, faulty or aged WWTP disinfection systems, waterfowl and wildlife, and stormwater runoff.
- Disinfection practices at some WWTPs had some lapses during the data collection period, but they have improved and now consistently comply with NPDES permit limits.
- Implementing a 72% FC load reduction at the mouth of Hangman Creek during July through September should be adequate to reduce FC loads throughout the year if actions are taken that treat low-flow and high-flow sources of contamination.

Recommendations

- The mouth of Hangman Creek and reaches where informal swimming occurs should be the highest priority areas for FC abatement action.
- Ecology will need to work with EPA, Coeur d'Alene Tribe, and Idaho to reduce FC loads in the upper Hangman Creek, Little Hangman Creek, and Rock Creek.
- Most sites require more sampling to better identify sources of bacteria and seasonal patterns, especially where livestock, wildlife, and waterfowl sources are suspected.
- Limiting Tekoa WWTP effluent FC counts to a monthly geometric mean of 100 cfu/100 mL and a weekly geometric mean of 200 cfu/100 mL would ensure downstream criteria are met during low-flow conditions.
- As required by the Municipal Phase 2 Stormwater NPDES Permit, permit holders must map their stormwater systems. If any stormwater entities determine that a stormwater outfall may be contributing bacteria to surface water, they should notify Ecology permit managers and work cooperatively to ensure FC reductions are achieved.
- All possible sources of FC should be addressed through source best management practices (BMPs).
- Limiting livestock access to waterways and riparian corridors should reduce low-flow and high-flow sources of fecal contamination.

Allocation for future growth

Hangman Creek watershed primarily has an agricultural land base. Conversions of agricultural land to residential or non-commercial farms are of concern in the watershed. However, bacteria levels could decrease or increase depending upon the agricultural source being converted. Rural stormwater and animal-keeping practices at non-commercial farms are the most likely sources of future FC loads from these land use conversions. These future potential sources should be adequately addressed by this TMDL in the following ways:

- The FC load reductions recommended in the TMDL have large margins of safety that will require significant implementation measures to ensure compliance. These margins of safety are adequate to require implementation measures that reduce the growth impact of FC loads from stormwater and non-commercial farms.
- Most of the future growth is expected to occur in the lower watershed where stormwater quality is controlled by jurisdictions under Phase 2 permits that have FC wasteload allocations that must be met. Phase 2 jurisdictions are required to control all new stormwater sources within their NPDES designated areas.
- Cheney and Spangle, the smaller municipalities expecting the largest growth, have good FC permit compliance records and require no FC reductions to meet their recommended wasteload allocations.

Margin of safety

The federal Clean Water Act requires that TMDLs be established with margins of safety (MOS). The MOS accounts for uncertainty in the available data, or the unknown effectiveness of the water quality controls that are put in place. The MOS can be stated explicitly (e.g., a portion of the load capacity is set aside specifically for the MOS). But, implicit expressions of the MOS are also allowed, such as conservative assumptions in the use of data, application of models, and the effectiveness of proposed management practices.

Implicit MOS assumptions were applied to the analyses to provide a large MOS for Hangman Creek FC TMDL evaluation. The FC database in most areas of the watershed was limited, so this increased the level of uncertainty in the FC loads and receiving water quality. The FC reductions and allocations are conservatively set to protect human health and beneficial uses to the fullest extent. The following are conservative assumptions that contribute to the MOS:

- The statistical rollback method was applied to FC data from the most critical season. Resultant TMDL target annual FC load reductions are more stringent than would be required under the listed Washington State *Primary Contact* and *Secondary Contact Recreation* FC criteria (i.e., the geometric mean or concentration not to be exceeded in more than 10% of the samples is more stringent than 100/200 cfu/100 mL).
- Since the variability in FC concentrations during low-flow conditions and storm events is usually quite high, the TMDL targets and percent reduction estimated by the statistical rollback method are conservative, especially if a 90th percentile is the critical criterion. In these cases, the high coefficient of variation of the log-normalized data can produce a 90th percentile value for the population greater than any of the sample results used to calculate the value. This is especially true at sites with fewer than 20 data points.
- The FC loading capacities and TMDL target load reductions for the several mainstem and tributary sites were conservatively calculated by including a historical data set with more frequent criteria violations.
- Instream die-off rates were not considered to calculate the cumulative FC loads in Hangman Creek.

- The Phase 2 stormwater permit wasteload allocations were included to focus future permit-holders' activities even though the critical conditions for most FC problems in the lower watershed, where most stormwater permits are located, are during low-streamflow conditions when stormwater flows are less likely to be generated.
- The WWTP reductions to meet wasteload allocations are based on past disinfection problems. Meeting the NPDES-permit limits should no longer be a problem since disinfection procedures have been improved at all WWTPs.

Temperature

Areas of concern

Problems with elevated temperatures in the Hangman Creek watershed have been under-reported. The *Washington State Department of Ecology 2004 Statewide Water Quality Assessment* has only three temperature listings in the Hangman Creek watershed (Ecology, 2005a). The mouth of Hangman Creek is on the 303(d) list as impaired for monthly data with instantaneous measurements taken by Ecology (Figure 17). Hangman Creek near Tekoa (RM 53.2) and at Bradshaw Road (RM 32.9) are two other sites listed as Category 2, waters of concern. Both are based on older instantaneous measurements collected by Ecology in 1988 (Carey, 1989) and 1999 (Ecology, 2005a).

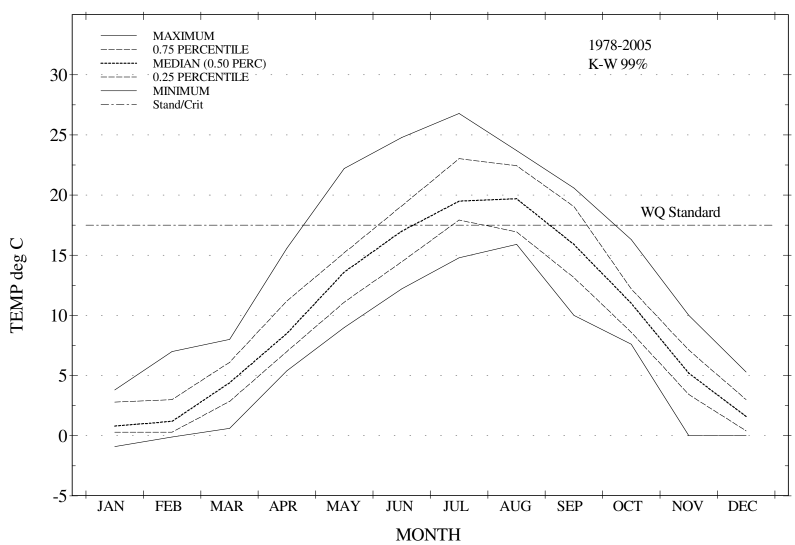

Figure 17. Monthly statistics for instantaneous temperature measurements taken at the mouth of Hangman Creek from 1978 to 2005 (Ecology Station 56A070).

A trend analysis of the monthly temperature data at the mouth of Hangman Creek is not possible because instantaneous measurements have not been collected at the same time of day over the period of record. Nor have they been collected at the time of the peak water temperature. As may be reasonably assumed, water temperatures are often highly influenced by the time of day.

Elevated temperatures in the watershed are now a documented, widespread, seasonal problem. The Spokane County Conservation District (SCCD) surveys in 1994 through 1997 measured instantaneous water temperatures greater than 17.5°C in Hangman Creek at State Line Road (RM 55) and Bradshaw Road (RM 32.9), the mouth of Little Hangman Creek, the mouth of Rattler Run Creek, and Rock Creek at Jackson Road (SCCD, 1999). At very low discharge conditions in 2004, Cove Creek, California Creek, and Marshall Creek also exhibit temperatures above 17.5°C (SCCD, 2005).

Continuous temperature monitoring data collected for the Hardin-Davis (2003) SNTEMP model calibration recorded elevated temperatures from June through September 2002 along Hangman Creek from Hays Road (RM 34.5) to the mouth (Figure 18). Average weekly temperatures exceeded 17.5°C through most of the monitored reach from mid-June to mid-September. The upper reaches of the creek were especially susceptible to elevated temperatures.

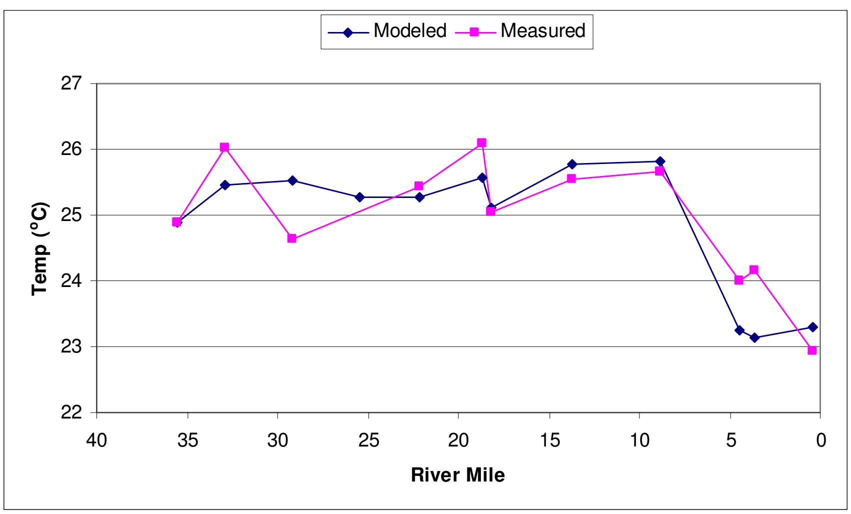

Figure 18. Weekly average stream temperatures measured and modeled at several sites along Hangman Creek for week 28 in July 2002 (Hardin and Davis, 2003).

Groundwater and springs consistently lower water temperatures between river mile 10 and the mouth of the creek. Figure 18 is an example of the trend recorded during the 2002 SNTEMP study. According to instream flow data collected for the study, water volumes double through that 10-mile reach, primarily from groundwater sources. Surface water inputs are minimal.

The SCCD surveys for the TMDL also documented instantaneous water temperatures greater than 17.5°C in Hangman Creek from the Idaho state line (RM 55) to Duncan Road (RM 18.7), the mouth of Little Hangman Creek, at the mouth of Rattler Run Creek, and on Rock Creek from Rockford to the mouth (SCCD, 2005).

Critical conditions

Existing conditions for stream temperatures in the Hangman Creek watershed reflect seasonal variation. Cooler stream temperatures occur in the winter, while warmer stream temperatures capable of exceeding criteria have been observed from late April through summer and into October. The highest temperatures typically occur from mid-July through mid-August (Figure 17); mid-summer is used as the critical period for developing the TMDL. Critical season adjustments may be necessary later if, for example, cooler temperatures are needed to protect life-stages for sensitive fish species. More restrictive point source temperature limits may apply to the entire spring to fall season if mixing zone or the instream 7-day average daily maximum temperature criteria are exceeded.

Seasonal estimates for streamflow, solar flux, and climatic variables for the TMDL are taken into account to develop critical conditions for the TMDL model. The critical period for evaluation of solar flux and effective shade was assumed to be August 1 because it is the mid-point of the period when water temperatures are typically at their seasonal peak. The SNTEMP modeling explored increased streamflow and shade, separately and together. The shade modeling, performed as a separate effort, evaluated the effect of additional shade in blocking radiant energy during the critical period.

Analytical framework

The theory and physical laws governing temperature and heat in streams are outlined in Appendix B. Equations based on these concepts have been applied to various tools and models used by scientists to simulate water temperature data. Ecology's scientists calibrate these models to local conditions after collecting information from the stream, the lands surrounding the stream, local weather stations, and maps. Then historical, current, and future stream temperatures are simulated to find the best ways to evaluate and protect aquatic organisms against extreme temperature effects.

The temperature TMDL is built from work previously conducted for the Hangman Creek Watershed Planning Unit under the Watershed Planning process. Hardin-Davis (2003) used data collected by the SCCD for a SNTEMP model. SNTEMP simulates mean daily temperatures along a stream under steady-state flow conditions (USGS, 2006). The model included 34.5 river miles from Hays Road to the mouth of Hangman Creek.

The SNTEMP model results and continuous temperature monitoring were adequate to determine the seasonal and spatial extent of the temperature problem in Hangman Creek. The field data documented that stream temperatures do not meet current water quality criteria all along the mainstem. The SNTEMP modeling demonstrated that average temperatures could not meet the criteria with small increases in flow (3 cfs) and with an increase in average reach shade conditions of 20% to simulated shade conditions of 70% (Hardin-Davis, Inc., 2003). Additional work was necessary to provide TMDL shade targets.

Ecology uses a condition referred to as the *system potential*. System potential is the estimated water temperature if mature riparian vegetation and microclimate conditions were present with other available groundwater, channel improvement, and flow augmentation terms in place. The modeled shade in the system-potential scenario is based on the soil, climate, and native vegetation characteristics normally found in an undisturbed riparian area. The system-potential shade is compared to the existing condition by the use of modeling procedures developed in Oregon and Washington.

The Geographic Information System (GIS) and modeling analysis was conducted using two specialized software tools:

1. Oregon Department of Environmental Quality's (ODEQ) Ttools extension for ArcView (ODEQ, 2001) was used to sample and process GIS data for input to the Shade model.
2. Ecology's Shade model (Ecology, 2003a) was used to estimate effective shade along the mainstem of Hangman Creek from the Idaho border to the mouth. Effective shade was calculated at 100-meter intervals along the streams and then averaged over 1000-meter intervals.

The SCCD collected densiometer readings for multiple transects at 10 sites along the main-stem as field verification of modeled shade (Appendix B, Table B2)

All input data for the Shade model are longitudinally referenced, allowing spatial inputs to apply to certain zones or specific river segments. Model input data were determined from available GIS coverages using the Ttools extension for ArcView, or from data collected by the SCCD or other data sources. Detailed spatial data sets were developed for the following parameters for model calibration and confirmation:

- The creek was mapped at 1:3,000 scale from one-foot resolution color Digital Orthographic photo Quadrangles (DOQs) of the watershed.
- Riparian vegetation size and density were mapped at 1:3,000 scale from the DOQs and sampled from the GIS coverage at 100-meter intervals along the streams in the study area.
- Effective shade was calculated from vegetation height and density with Ecology's Shade model.
- Near-stream disturbance zone widths were digitized at 1:3000 scale.
- West, east, and south topographic shade angle calculations out to nine miles were made from the 10-meter digital elevation model (DEM) grid using ODEQ's Ttools extension for ArcView.
- Stream elevation was sampled from the 10-meter DEM grid with the Milagrid ArcView extension. Gradient was calculated from USGS 1:24,000 quad maps.
- Aspect (streamflow direction in decimal degrees from north) was calculated by the Ttools extension for ArcView.

Tributaries were not analyzed directly from orthographic photos and GIS tools. The tributaries and perennial streams in the Hangman Creek watershed are narrow enough that riparian vegetation shade would usually dominate stream cooling compared to geographic features. Shade curves and a shade table were created from the Shade model vegetation regional analysis. Shade potential for tributaries can be estimated when channel aspect and bankfull width are known.

Point source temperature wasteload allocations required additional modeling. Since Hangman Creek is effluent-dominated in some areas, a model was required to estimate the upstream temperatures now and after system-potential shade was added. The upstream temperatures, as natural conditions, can then be used to estimate the monthly average maximum effluent temperature during the critical season and set a temperature wasteload for the Tekoa WWTP.

The rTemp model predicts a time series of water temperatures in response to heat fluxes determined by meteorological data, groundwater inflow, and hyporheic exchange and conduction between water and benthic sediment (www.ecy.wa.gov/programs/eap/models.html). Shade model results and appropriate meteorological and discharge data for the receiving water at Tekoa were supplied to the model to generate the temperature time series under current and system-potential shade conditions.

Calibration of SNTEMP, Shade, and rTemp models

According to Hardin-Davis, Inc. (2003), only minor adjustments were needed in the SNTEMP model to match measured temperatures. Several graphs are available in their report. The calibration narrative continues:

The wind speed parameter in SNTEMP is the primary calibration tool. When the weekly average wind speed input values were varied from 4 to 16 miles per hour…, the modeled temperatures showed good agreement with measured temperatures during most weeks, and at most sites… The median absolute error was 0.5ºC, and 79% of the errors were less than 1ºC. Root mean squared errors were under 1ºC for most weeks and sites. Given this level of agreement, no further calibration adjustments were made.

Weeks 27 and 33 had the poorest agreement; simulated temperatures were too high by an average of 1.5ºC in week 27, and too low by 0.75ºC in week 33. These results could have been due to discrepancies between conditions at the meteorological station (Spokane Airport) and local conditions. Among the sites, RM 29.2 and Avista Substation Bridge (RM 3.6) had the largest errors. SNTEMP over-predicted temperature at RM 29.2 by an average of 1.05ºC; this may have been because the actual topographic shading effect in the canyon was greater than estimated. The model under-predicted temperatures by 0.81ºC at Avista Substation Bridge, probably because groundwater cooling was less than estimated.

Weekly average temperatures at all sites…showed a peak at week 28 (mid-July), and a secondary peak at week 34 (late August). The simulated behavior was consistent with measured values. Longitudinally, the pattern was more complex. Depending on the week, the temperature either increased gradually from RM 35.5 to RM 8.8, or varied erratically. In either case, water *temperature was at or near its longitudinal maximum at RM 8.8. Temperature dropped sharply from there to RM 3.6; SNTEMP followed the measured data closely over this distance.*

Maximum temperatures (weekly average maxima) measured by SCCD were 1.0º to 5.2ºC greater than weekly averages…The greatest differences were in the upstream portion of the reach, where shade and groundwater are minimal…SNTEMP is designed for best results with average, as opposed to maximum temperatures; thus, no comparisons were made between measured and simulated maxima. The effects of scenarios on temperature maxima were not simulated with SNTEMP.

The shade model was calculated and compared to densiometer measurement collected by SCCD field staff (Figure 19). The shade model accounts for topographic shading, so model results were generally higher than densiometer measurements. However, field data and model results were in good agreement where riparian vegetation was the dominant form of shade available.

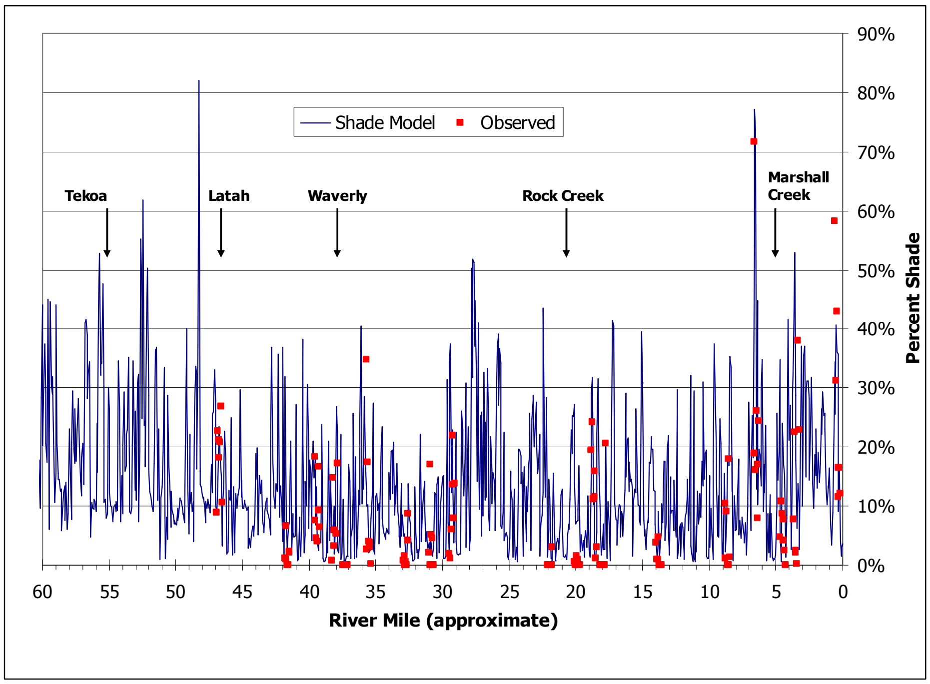

Figure 19. Current shade along Hangman Creek comparing shade model results to canopy closure measurements taken by the SCCD with densiometer transects at selected locations.

The rTemp model was calibrated to instream water temperatures for spring and summer 2002 conditions near Tekoa WWTP (Figure 20). The SCCD (Hardin and Davis, 2003) had placed temperature monitors in Hangman Creek at Tekoa from February through August, recording temperatures every two hours. Hourly Spokane Airport air temperatures and SCCD streamflow records for the same time period were also entered into the model.

The model was calibrated to simulate peak water temperatures during the critical summer period by limiting stream depths and groundwater flows to conditions typical of July and August under current riparian and landscape shade conditions. The model simulation was acceptable: within 0.7º C of the observed 7-day average daily maximum temperatures in July. As with the SNTEMP model calibration, Spokane Airport wind speeds were reduced to better match daily water maximum temperatures. Extrapolating temperature data from the airport to local conditions is probably the largest source of error. However, this can only be verified after local air temperature data are collected and the model re-run.

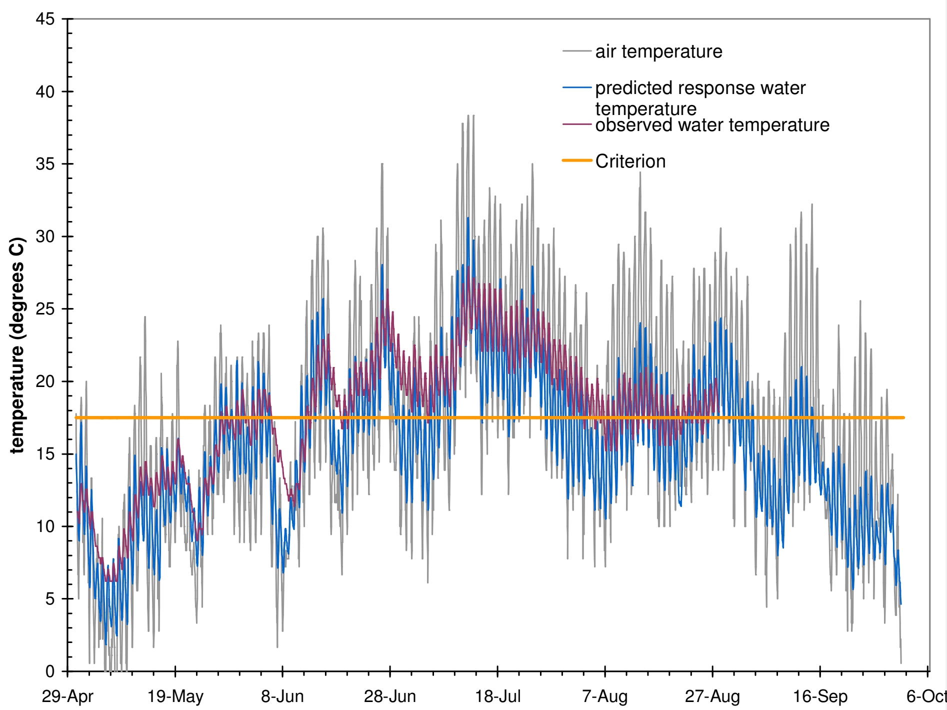

Figure 20. Hangman Creek water temperatures at Tekoa from the rTemp model compared to observed local water temperatures and air temperatures recorded at Spokane Airport from April to October 2002.

Loading capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with standards. EPA's current regulation defines loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (40 CFR § 130.2(f)). Water temperature loading capacities in the Hangman Creek watershed are solar radiation heat loads based on potential riparian land cover (primarily vegetation).

The *system-potential temperature* is an approximation of the water temperature that would occur under natural conditions during specified conditions of air temperature and streamflow. The system-potential temperature is estimated using analytical methods and computer simulations proven effective in modeling and predicting stream temperatures in Washington (Baldwin and Stohr, 2007; Cristea and Pelletier, 2005; Pelletier and Bilhimer, 2004). The system-potential temperature is based on our best estimates of the *mature riparian vegetation and riparian microclimate* that did not include human modifications, along with any known groundwater, surface water, or channel conditions.

A system-potential temperature is estimated for the summer low-flow *critical condition* of upper 90th percentile air temperatures and low streamflows that occur only once every ten years. The system-potential temperature does not, however, replace the numeric criteria, nor invalidate the need to meet the numeric criteria at other times of the year and at other less extreme low flows and warm climatic conditions.

At locations and times where the system-potential temperature is warmer than the numeric criteria assigned to the waterbody, or within 0.3ºC of the criteria, the loading capacity and load allocations in this TMDL are to be based on not allowing cumulative human sources to increase the seven-day average daily maximum (7DADM) water temperature by more than 0.3°C. To reiterate, the following sections from the state water quality standards apply:

Numeric threshold temperature criteria are established in the state water quality standards [WAC 173-201A-200(1)(c)]. These numeric criteria are designed to ensure specific communities of aquatic life will be fully protected whenever and wherever the numeric criteria are met. The state standards recognize, however, that some waterbodies may not be able to meet the numeric criteria at all places and all times.

WAC 172-201A-200(1)(c)(i) states that: "When a water body's temperature is warmer than the criteria in Table 200(1)(c) (or within 0.3ºC (0.54ºF) of the criteria) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-day average daily maximum (7DADM) temperature of that water body to increase more than 0.3ºC (0.54ºF).

The air temperatures used to evaluate statewide critical conditions are referenced to average July and August temperatures in 1997 (as an average-flow year) and 1998 (as a low-flow year) (Stohr, LeMoine, and Pelletier, 2007). The 2002 July and August air temperatures in Spokane were not too dissimilar from these reference conditions (Table 17). The 2002 temperatures were slightly warmer in June and July than in 1997, but not as warm as in 1998. However, monthly discharges in the creek were much lower in 2002 than in 1997 or 1998 (Table 7). Therefore, it is likely the 1997, 1998, and 2002 conditions in Hangman Creek were comparably critical in terms of water temperature because of the lower flow volumes available in 2002 to buffer solar heating.

Table 17. The average monthly air temperature in degrees centigrade reported at the Spokane Airport for June through September in 1997 through 2004.

Year	June	July	Aug	Sept
1997	15.52	**19.75**	**21.63**	16.59
1998	16.94	**24.03**	**22.03**	18.38
1999	15.51	18.98	21.27	15.07
2000	16.10	19.90	19.75	13.21
2001	14.82	20.22	21.70	17.37
2002	16.82	**21.84**	**19.12**	14.71
2003	17.56	22.77	21.26	16.61
2004	17.56	22.35	21.66	14.44

Bold = reference years (1997-98) and monitored year (2002)

Hardin-Davis Inc. (2003) noted that the water temperature conditions in the creek were a result of inadequate channel shading and low seasonal discharge volumes with very little groundwater interaction. They also noted that average temperatures observed and modeled in the creek exceeded recommended guidelines for trout survival, and could not be brought within guidelines with 70% riparian shade on all reaches and a net 3 cfs flow increase. Stream channel restoration activities were not assessed.

Ecology further analyzed the effects of shade to determine the system potential and to calculate the loading capacity. Instead of applying a single 70% shading factor to all reaches, an evaluation of landscape and vegetation shading effects on the creek was conducted. Channel width and aspect were considered in the evaluation.

SCCD (2003b) evaluated pre-settlement watershed conditions using historic plant community cover as described in early section line surveys. These descriptions were discussed under *Watershed Description* in this report and used to estimate what plant species would be present near streams and drainages for the temperature analysis. Washington Department of Natural Resources (DNR) and Natural Resources Conservation Service reference data also helped establish potential vegetation heights. The potential maximum vegetation height had a range of 71–102 feet. Based on field observations and historical data, a two-layered, 100-foot riparian zone was simulated:

1. A 35-foot zone of 30-foot willows and alders with a 75% density next to the banks.
2. A pine forest located another 65 feet out, with tree heights of 80 feet and a 50% density.

This is a generalized scheme of the potential mature riparian vegetation that would be present in much of the watershed. A different set of riparian vegetation metrics may be more appropriate at individual sites as restoration occurs, especially in the Columbia Plateau Ecoregion areas. The riparian areas of the Columbia Plateau Ecoregion may not be able to support the pine forest, and tree heights may be shorter. Channel restoration also can influence the outcome of shade efficiencies from riparian vegetation and needs to be considered for maximum thermal reduction.

The Hangman Creek mainstem model results for system-potential shade compared to the current shade conditions are graphically displayed in Figure 21. The amount of solar radiation gained in terms of watts per square meter (W/m^2) along the creek under the two conditions is also displayed in Figure 22. Notice how potential riparian shading is enhanced by the east to west orientation of the creek near Tekoa, and by the canyon features at RM 22 to 28. The average difference in current and system-potential shade was 26% with the greatest need for additional shade in the upper 18 miles of the watershed and near the mouth.

Hangman Creek system-potential scenario assumed no changes in streamflow, groundwater, or channel depth and width terms. Improvements in any of these factors could also influence instream temperatures. Wetland restoration, channel restoration to reduce streambank erosion, and other practices to improve habitat in the watershed could also improve water temperatures.

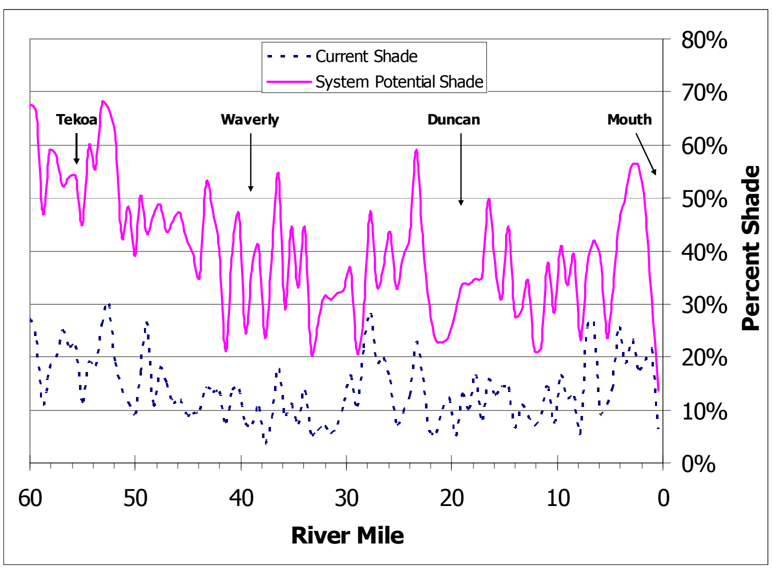

Figure 21. Current conditions and system-potential shade estimates (1000 meter averages) along Hangman Creek based on the shade model.

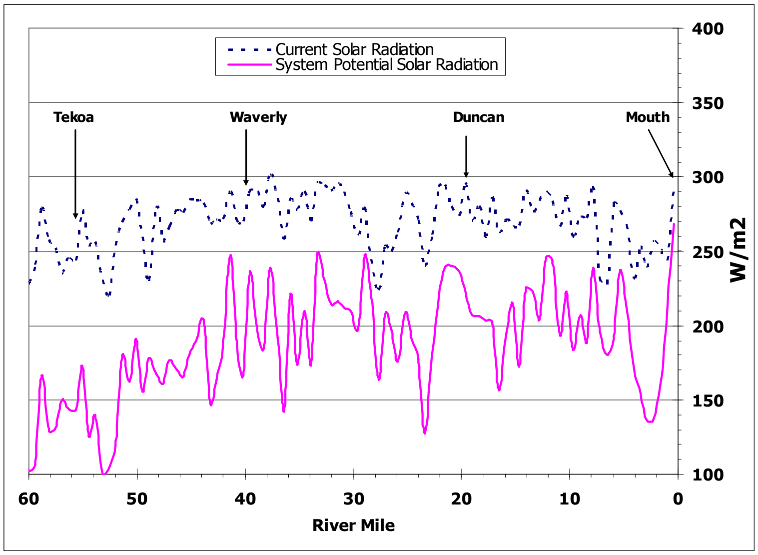

Figure 22. System-potential thermal loads along Hangman Creek compared to loads under current conditions based on shade and aspect inputs to the Shade model. Thermal loads are in terms of watts per square meter (W/m^2).

Load and wasteload allocations

Load allocations (for nonpoint sources) and wasteload allocations (for point sources) are established in this TMDL to meet both (1) the numeric threshold criteria, and (2) the allowances for human warming under conditions that are naturally warmer than those criteria.

Since Hardin-Davis (2003) demonstrated that system-potential water temperatures in most of Hangman Creek would not meet numerical water quality standards during the hottest period of the year, there is a need to achieve maximum protection from direct solar radiation. The load allocations are then based on effective shade from maximum system-potential mature riparian vegetation (i.e., that vegetation which can grow and reproduce on a site given climate, elevation, soil properties, plant biology, and hydrological processes.) The load allocations, in terms of heat and effective shade, for the mainstem of Hangman Creek are quantified in Appendix B, Table B4.

The model estimates suggest current shade needs increases of 7% to 43% along the mainstem to meet effective shade requirements (Appendix B, Table B4). Table 18 provides the heat load allocation and required vegetation shading terms for individual sites along Hangman Creek on the 2004 303(d) list and those proposed for the 2006/2008 303(d) list. These segments of Hangman Creek need effective shade of 21% to 60%, and shade increases over current conditions of 13% to 41%.

Tributaries are also listed in the Table 18. These were not directly modeled, so they require a different approach. The application of a shade curve based on the system-potential shade used in the Shade model for the mainstem Hangman Creek is proposed as a load allocation mechanism.

Table 18. Heat load allocations and shade requirements for 2004 and 2006/2008 303(d) listed sites in the Hangman Creek watershed based on the Shade model results.

Waterbody	Listing ID	Section, Township, Range	Location	W/m^2	Shade Required[1]
Rattler Run	48303	Section 16 T22N R44E	Rattler Run at mouth	Shade curve	Shade curve
Rock Creek	48333	Section 12 T23N R43E	Rock Creek mouth	Shade curve	Shade curve
California Creek	48340	Section 03 T23N R43E	Calif. Creek mouth	Shade curve	Shade curve
Marshall Creek	48368	Section 31 T25N R43E	Marshall Cr. mouth	Shade curve	Shade curve
Hangman Creek	48370	Section 36 T25N R42E	River mile 3.6	172	45%
	48371	Section 31 T25N R43E	Above Marshall Creek	212	32%
	48372	Section 28 T24N R43E	Hangman Valley Golf	225	28%
	48373	Section 33 T24N R43E	River mile 18.2	206	34%
	48374	Section 11 T23N R43E	Duncan Road	207	34%
	48375	Section 13 T23N R43E	Latah Road	181	42%
	48376	Section 08 T22N R44E	Keevy Road	198	37%
	48377	Section 16 T22N R44E	Bradshaw Road	247	21%
	48378	Section 28 T22N R44E	Hays Road	222	29%
	48379	Section 01 T21N R44E	Roberts Road	187	40%
	48380	Section 30 T21N R45E	Spring Valley Road	165	47%
	48381	Section 09 T20N R45E	Fairbanks Road	162	48%
	48382	Section 24 T20N R45E	Above Tekoa WWTP	126	60%

[1]Shade Required is the percentage of the stream that needs to be covered by effective shade.
W/m^2 is heat measured in watts per square meter .
Tributary values need to have site-specific metric collection and application of the shade curve in Figure 23.

For all tributaries and perennial streams in the watershed with temperature criteria violations, the load allocations for shade from Figure 21 and Table B3 (in Appendix B) can be applied. This is based on the estimated relationship between shade, channel width, and stream aspect at the assumed maximum riparian vegetation condition used in the Hangman Creek mainstem Shade model. Perennial streams include those that would naturally have flow year-round but are dry part of some years due to drought.

Many tributary and perennial stream channels in the Hangman Creek watershed, including those in Table 18, are narrow enough to be influenced more by vegetation shade than by landscape shade. However, landscape may be a factor for tributaries in deep narrow canyons. As metrics are collected for sites in these areas, site-potential effective shade can be assigned as a load allocation from Figure 23 and the accompanying Table B3, Appendix B. The assigned load allocations are expected to result in water temperatures that are equivalent to the temperatures that would occur under natural conditions. Therefore, the load allocations are expected to meet the water quality standard.

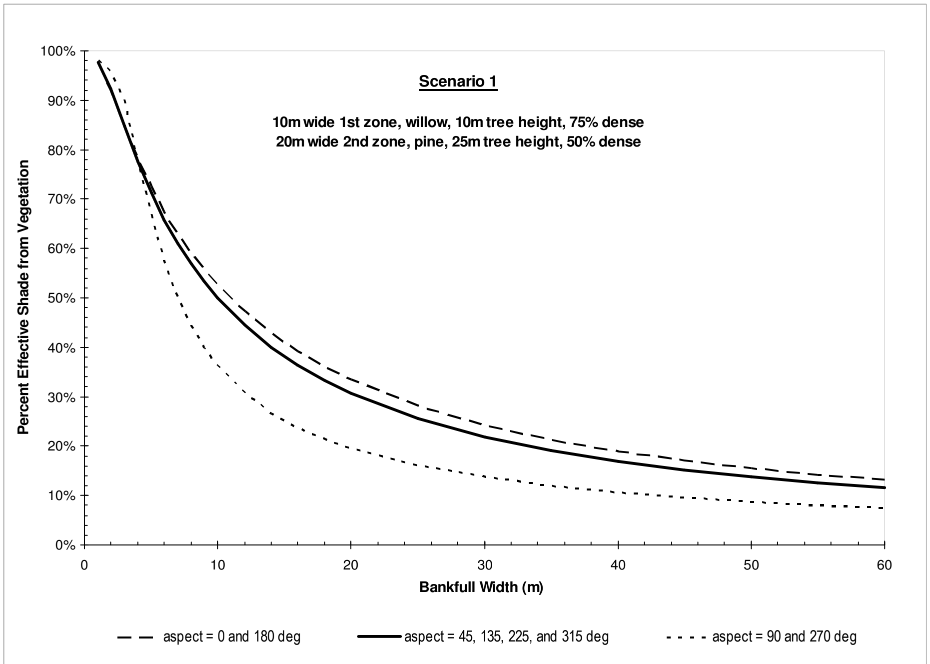

Figure 23. Shade curve constructed for sites in the Hangman Creek watershed based on system-potential vegetation maximum heights and stream orientation (aspect) to sunlight in August. (A stream that runs north and south has an aspect of 0 and 180 degrees).

The water quality standards allow an increase of 0.3ºC over naturally warm conditions for cumulative human actions that can be factored into setting wasteload allocations. Because water temperatures might exceed 17.5ºC on a 7-day average daily maximum (7DADM) in areas of the watershed from late-April through October, all point sources require temperature wasteload evaluations. Unfortunately, few of the six WWTPs have monitored effluent or background temperatures, and temperature information is not available for stormwater discharges. However, only Tekoa and Spangle WWTPs discharge during the hottest period of the year when effluent may pose the most serious instream temperature problem.

The system-potential shade for Tekoa from the Shade model was used as input to the rTemp model to estimate when the natural condition would be greater than 17.5ºC (Figure 24). As discussed earlier, 2002 is considered a reasonably warm year to use as a critical period. In this way the effluent temperature limits for the Tekoa WWTP were estimated until more site-specific data can be collected. Ecology Water Quality Program guidance now requires NPDES permittees to collect adequate data to characterize effluent and background receiving water temperatures, as well as the available dilution during critical conditions. Besides using these data to set effluent limits, the data will also be used to further establish or refine the wasteload allocations set in this TMDL.

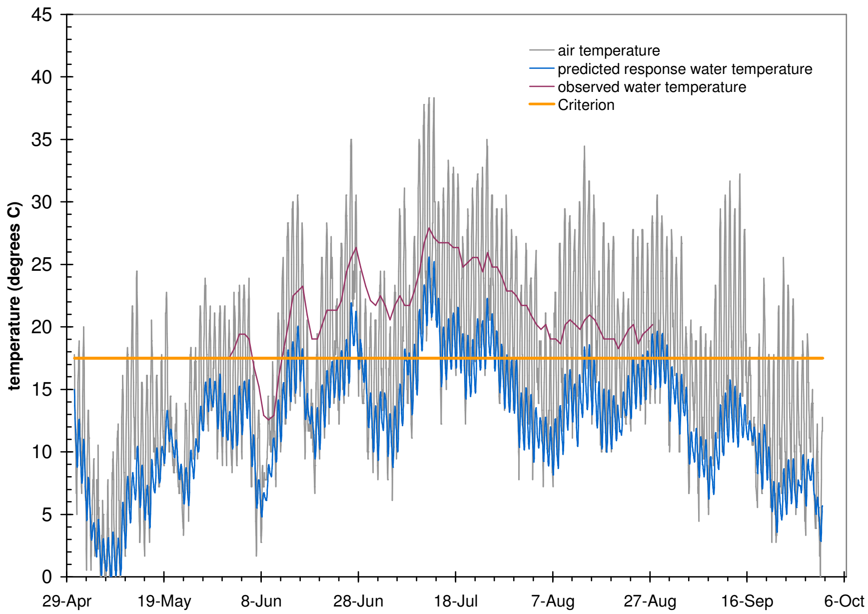

Figure 24. The rTemp model output for Hangman Creek at Tekoa. System-potential shade conditions (predicted response) water temperatures are compared to observed water temperatures in 2002. The 7-day average daily maximum (7DADM) temperatures in June through August would continue to exceed the 17.5ºC criterion.

According to the model results and analysis, only periods of June through August would have had 7DADM temperatures above 17.5ºC under system-potential shade conditions. According their NPDES permit factsheet, Tekoa WWTP's chronic and acute dilution factors are 1.2 and 1.02, respectively. Because no dilution is available for the Tekoa WWTP effluent during low flow conditions, the effluent temperature limit would need to be based on a monthly upstream temperature statistic and assumes little or no dilution.

The monthly averages of 7DADM temperatures under system-potential shade conditions were the chosen statistics for effluent maximum temperatures (Table 19). The wasteload allocations for Tekoa WWTP during periods of elevated upstream temperatures over the 17.5º C criterion are recommended as 7DADMs in June, July, and August of 18.2º C, 21.5º C, and 17.7º C, respectively.

As a note, effluent discharges from point sources are also regulated under permit to meet (1) incremental warming restrictions established in the standards when the threshold criteria are being met (background cooler than the criteria), and (2) restrictions to avoid instantaneous lethality to fish and other aquatic life. The purpose of these restrictions is to ensure that sources prevent unreasonable warming of the background receiving water from an effluent discharge that may impact the aquatic life uses or impact the general temperature regime of the watershed. The water quality standards at WAC 173-201A-200(1)(c) (i) – (vii) contain these restrictions and other notes on implementation of the temperature threshold criteria.

Table 19. Estimated water temperatures in Hangman Creek above Tekoa WWTP under system-potential shade conditions when 7-day average daily maximums (7DADM) approach the 17.5ºC criterion. Estimates are based on an rTemp model calibrated to 2002 field data.

June			July			August		
Day	ºC	7DADM	Day	ºC	7DADM	Day	ºC	7DADM
6/11	14.2		7/7	18.2	21.5	8/9	16.2	
6/12	15.5		7/8	17.9	22.1	8/10	16.6	
6/13	18.1		7/9	18.6	22.3	8/11	15.4	
6/14	18.8	17.1	7/10	21.4	22.6	8/12	16.2	17.0
6/15	20.1		7/11	23.4	22.6	8/13	18.4	
6/16	18.2		7/12	25.6	22.6	8/14	18.6	
6/17	14.7		7/13	25.2	22.6	8/15	17.4	
			7/14	22.3	22.6			
6/23	17.6		7/15	20.0	22.6	8/23	17.5	
6/24	18.1		7/16	20.6	22.6	8/24	17.0	
6/25	19.0		7/17	21.1	22.6	8/25	17.7	
6/26	21.9	19.2	7/18	21.6	22.3	8/26	18.1	18.4
6/27	21.2		7/19	19.5	21.5	8/27	19.4	
6/28	19.0		7/20	19.3	20.6	8/28	19.6	
6/29	17.4		7/21	19.0	20.2	8/29	19.4	
			7/22	20.6	20.3			
			7/23	20.5	20.3			
			7/24	22.3	20.3			
			7/25	21.0	20.3			
			7/26	19.7	20.3			
			7/27	18.6	20.2			
			7/28	17.7	20.1			
June Average: 18.2			July Average: 21.5			August Average: 17.7		

The allowable effluent 7DADM effluent temperature under these conditions essentially will be at the upstream receiving water temperature and allow no incremental increase in receiving waters. Ecology will also apply these same limits to the Spangle WWTP as well until more site-specific data can be collected. Both limits may be modified in the future as more data become available.

See my previous comments and those in the exec summary above. Wastewater discharges from constructed wetland treatment systems are just another point source and therefore need numeric WLAs if they discharge pollutant(s) which can affect water quality. **Ecology believes treatment systems that include wetland components can be excluded from these temperature restrictions as long as the wastewater entering the wetland does not increase the**

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temperature of the wetland. Effluent temperatures from the wetland treatment system should not be more than what would occur from a natural wetland with similar size and flow regime characteristics (Hicks, 2007). In the Hangman Creek watershed, three WWTPs fall into this category; historically they have rarely discharged effluent during the critical season:

- **Fairfield (Rattler Run)**
- **Freeman School District (Little Cottonwood Creek)**
- **Cheney (Minnie Creek)**

As with the all NPDES-permitted discharges in the state, these WWTPs will need to increase monitoring frequency of temperatures in the wetland and receiving water to ensure the wetland system is functioning properly. If monitoring demonstrates this assumption is not occurring, temperature limits will need to be established.

If Rock Creek 7DADM temperatures reach the 17.5ºC criteria in April or May while streamflows are low, Rockford WWTP effluent can reach a 7DADM of 18.25 ºC when the minimum permitted dilution factor of 3.5 is available in Rock Creek. Are these situations common or very rare? Rockford WWTP cannot discharge during the most critical months of June through August. Additional monitoring data required by the Ecology Water Quality Program policy for NPDES permittees should supply site-specific data so effluent temperature limits can protect Rock Creek water quality. The TMDL needs to specify WLAs in terms that can be easily applied as limitations by permit writers. So, as I read the above the appropriate WLA would seem to be:
Rockford WWTP --- no discharge from June through August AND no discharge in April/May (September?) when effluent temperature is above 17.5 and receiving water to discharge dilution is less than 3.5/1

Ecology's permit managers, in cooperation with stream restoration entities, will need to ensure streamside shading and other heat reduction measures are conducted in coordination with WWTP facilities. Effluent temperature allocations will become better defined as stream temperatures are lowered to their system potentials. All of the WWTPs should monitor upstream receiving water (when water is flowing in the stream) and effluent temperatures and discharge volumes during the spring through fall season. When the thermal and dilution cycles are better understood, compliance schedules and operational/facility options can be better designed in coordination with watershed actions.

Spokane County, the City of Spokane, and WSDOT have Phase 2 municipal stormwater permits. The most critical season (June through August) rarely has storm events of enough intensity and duration to generate significant municipal stormwater that would increase stream temperatures over a 7-day period. However, the late-April and May spring period and the September to October fall season may be susceptible to stormwater effects. There is no current evidence that stormwater increases Hangman Creek temperatures, but permit holders need to evaluate their systems and receiving waters. If thermal increases occur in Hangman Creek from municipal stormwater, wasteload allocations will be necessary.

I recommend a table be included which identifies all the point sources in the watershed and the WLAs which apply to each.

Conclusions and recommendations

The following conclusions and recommendations are based on this temperature TMDL evaluation:

Conclusions

- Many reaches of Hangman Creek and its tributaries cannot meet the 7-day average daily maximum (7DADM) 17.5º C temperature criterion during the critical summer low-flow period.
- Groundwater and springs play an important cooling role in the lower 10 miles of Hangman Creek below its confluence with Marshall Creek.
- A buffer of mature riparian vegetation along the banks of the creek and its tributaries is expected to decrease instream average daily maximum temperatures to system-potential levels.
- Site specific metrics of channel width and aspect will be necessary to apply the shade curve load allocations to tributaries and perennial streams.

Recommendations

- Channel restoration measures, including the restoration of a functioning riparian area, should be implemented throughout the watershed to reduce heat loads on the stream.
- Monthly wastewater treatment plant (WWTP) effluent 7DADM temperatures for facilities in Tekoa and Spangle are based on receiving water temperatures in June through August under system-potential shade conditions. Additional temperature monitoring data required in NPDES permits will allow refinement of these 7DADM effluent limits.
- Cheney, Fairfield, and Freeman School District wetland treatment system effluents do not usually discharge when instream receiving water temperatures are greater than 17.5 ºC. Ecology NPDES permit guidance expects wetland system temperatures to function as natural systems. Monitoring the temperature of discharges will be required to ensure this is the case.
- Rockford WWTP does not discharge effluent during critical temperature months, but additional temperature monitoring will be required under Ecology policies. Some effluent temperature limits may be necessary during low streamflow and elevated temperature conditions in April and May.
- All WWTPs should comply with Ecology Water Quality Program policy requiring receiving water and effluent temperatures and discharge volumes monitoring during the spring through fall season. These data will help to understand thermal and dilution cycles so that compliance schedules and operational/facility options can be designed.

- Watershed managers will need to ensure streamside shading and other heat reduction measures are conducted in coordination with WWTPs. Effluent temperature allocations will become better defined as stream temperatures are lowered to their system potentials.
- Spokane County, the City of Spokane, and WSDOT Phase 2 municipal stormwater thermal effects are not expected to impact Hangman Creek because 7-day storm events are unlikely during the June to August critical period. But, permit holders should evaluate their systems and prevent stormwater heating of Hangman Creek, especially during the late spring and early fall periods.

Allocation for future growth

The Hangman Creek watershed primarily has an agricultural land base. Conversions of agricultural land to residential or non-commercial farms are of concern in the watershed. These conversions are expected to occur in lower catchments of the watershed. Requirements for riparian shade and channel improvements recommended by this TMDL will remain the same as land is converted, so no additional allocation for future growth is necessary. No other point sources (e.g. WWTPs) are anticipated in the next five to ten years. Stormwater effects will be controlled through county, city, and state stormwater permits.

Margin of safety

The federal Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The MOS accounts for uncertainty in the available data or the unknown effectiveness of the water quality controls that are put in place. The MOS can be stated explicitly (e.g., a portion of the load capacity is set aside specifically for the MOS). But, implicit expressions of the MOS are also allowed, such as conservative assumptions in the use of data, application of models, and the effectiveness of proposed management practices.

Implicit MOS elements were applied to analyses to provide the MOS for Hangman Creek temperature TMDL evaluation. The temperature TMDL requires shading and long-term implementation of riparian and channel improvements that take several years. The heat reductions and allocations are conservatively set to aquatic community health and beneficial uses to the fullest extent. The following are conservative assumptions that contribute to the MOS:

- Data were collected under conditions equivalent to 7-day average flows during July-August with recurrence intervals of 10 years (7Q10). Allocations are set to protect stream temperatures under reasonable worst-case conditions.
- The load allocations are set to the effective shade provided by full mature riparian shade, which are the maximum values achievable in the Hangman Creek watershed. The riparian vegetation scheme applied to Hangman Creek is conservative in that some riparian areas in the Columbia Plateau Ecoregion may not be able to support vegetation heights assigned.
- The load allocations and calculations for the temperature TMDL are based on protecting salmonid species that are not known to be currently present. Protective measures to meet these more restrictive criteria may allow potential re-establishment of some absent species.

Turbidity and total suspended solids

Figure 25. An example of bank erosion in an agricultural area of Hangman Creek.

Areas of concern

Turbidity and suspended solids have been longstanding problems in Hangman Creek. In 1980 and 1988, Hangman Creek Water Quality Index scores were among the worst in the state for turbidity and suspended solids (Singleton and Joy, 1981; Hallock, 1988). Naturally eroding streambanks and upland soils in various parts of the watershed have been further destabilized by poor road building and agricultural practices (Figure 3 and Figure 25). The sediment that reaches the streams and its associated turbidity degrade aquatic habitats and transport excessive amounts of nutrients in Hangman Creek and the Spokane River.

According to Ecology's monthly monitoring data from samples collected at the mouth of Hangman Creek, suspended sediment concentrations and turbidity have decreased over the past 10 years (Figure 26 and Figure 27). Lower than normal streamflow volumes are partly the cause, but channel restoration efforts and improved riparian practices have also helped reduce sediment transport (SCCD, 2002). Some farmers have switched to less erosion-prone crops or have gone to more conservation-minded methods of farming.

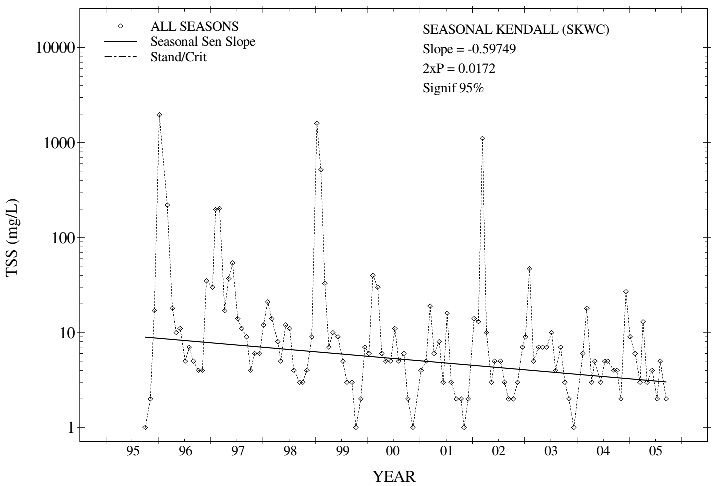


Figure 26. The total suspended solids (TSS) trend from 1995–2005 from monthly samples in Hangman Creek at Ecology station 05A070.

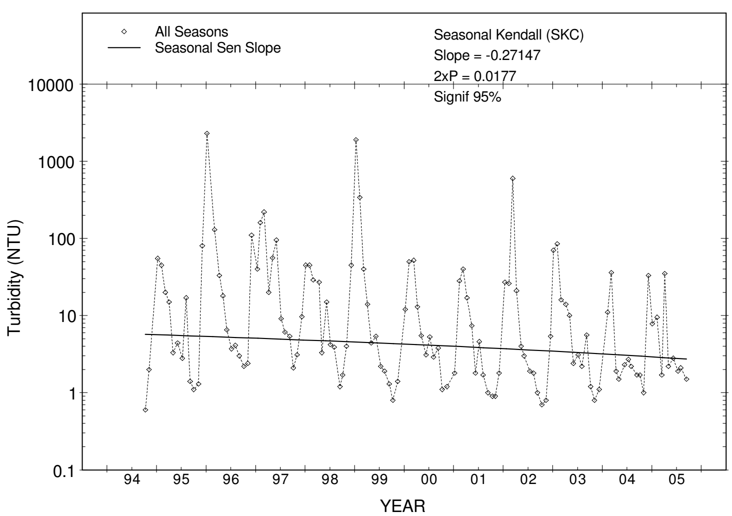


Figure 27. The turbidity trend from 1994–2005 from monthly samples in Hangman Creek at Ecology station 05A070.

Analyses of bed and suspended sediment loads by the USGS and the SCCD (SCCD, 2002) from 1998 to 2001 show wide annual variability depending on streamflow volumes and high-flow frequency characteristics (Table 20). This evaluation stated that most bed load is from the lower reaches of the Hangman watershed, whereas both the upper and lower reaches contribute to the suspended sediment load.

Table 20. Annual sediment discharge estimates from samples collected at the mouth of Hangman Creek by the USGS and the SCCD from 1997 through 2001 (SCCD, 2002).

Water Year	Annual Suspended Sediment Load (tons)	Annual Bed Load (tons)	Annual Total Sediment Load (tons)	Annual Average Discharge (cfs)
1998	35,200	5,100	40,300	166
1999	175,000	14,000	189,000	315
2000	83,000	12,300	95,300	273
2001	3,430	1,310	4,740	83.7

Four areas of Hangman Creek have been listed for turbidity criteria violations (Table 21). The listings are based on work performed by the SCCD in 1994 through 1997 (SCCD, 1999).

Table 21. Areas of Hangman Creek on the 2004 303(d) list for turbidity.

Waterbody	Parameter	Listing ID	Section, Township, Range
Hangman Creek at Bradshaw Rd	Turbidity	40942	Section 16 T22N R44E
Little Hangman Creek	Turbidity	40940	Section 13 T20N R45E
Rattler Run Creek	Turbidity	40941	Section 16 T22N R44E
Rock Creek	Turbidity	40943	Section 23 T23N R44E

To determine a violation of the turbidity water quality standard the current conditions are compared to a background or reference condition. Unfortunately a true background or reference condition does not exist for these streams. When listing these waterbodies for turbidity, Ecology compared the current conditions at each site to the turbidity at the state line (Hangman Creek at StateLine) to determine if an impairment was occurring in Washington. The elevations in turbidity that occurred in Washington indicated that sources within Washington add to the turbidity in the streams beyond acceptable levels and impair water quality.

These listings call attention to the serious problem of erosion and the excessive sediment transport in the Hangman Creek watershed. As will be shown in this analysis, the designated use of "salmonid spawning, rearing, and migration" is impaired by elevated suspended sediment. Therefore, it would also have been appropriate to list these streams as impaired by total suspended solids under the narrative criteria (WAC 173-201A-260):

> *(2) Toxics and aesthetics criteria. The following narrative criteria apply to all existing and designated uses for fresh and marine water:*
>
> > *(a) Toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive*

biota dependent upon those waters, or adversely affect public health (see WAC 173-201A-240, toxic substances, and 173-201A-250, radioactive substances).

Monitoring at the state line by the SCCD (1998) and the Coeur d'Alene Tribe (Peters, Kinkead, and Stanger, 2003) indicates water quality is degraded by elevated suspended sediment upstream in Idaho. Rock Creek and Little Hangman Creek also have significant portions of their watersheds across the border with elevated TSS events (Peters, Kinkead, and Stanger, 2003). Reductions will need to occur throughout the entire watershed to address the turbidity and suspended sediment problems. Upstream jurisdictions are required to meet downstream water quality standards at the jurisdictional boundaries. Therefore, Idaho is required to meet the Coeur d'Alene Tribe's standards at the reservation border and the Coeur d'Alene Tribe is required to meet Washington's standards at the state line. The Idaho Department of Environmental Quality (IDEQ) has completed a TMDL for the upper watershed (approximately 10,000 acres) that set locations and reductions for sediment. The Coeur d'Alene Tribe has collected data for the development of a TMDL for their reservation. The Tribe has participated in the development of Washington TMDLs and concurs with the assumptions used in the modeling (personal communication with Scott Fields, email 1/16/09).

The effects of suspended sediment on fish and benthic macroinvertebrate communities have been documented on both sides of the border. Intensity and duration of turbidity and suspended sediment events are important factors to consider when assessing effects on aquatic life. Cold water aquatic organisms in the Pacific Northwest have evolved to tolerate varying concentrations of suspended sediment of short duration. Extreme concentrations or long periods of intense or moderately-elevated suspended sediment can permanently change community structure and behavior (Newcombe and McDonald, 1998). The state turbidity criteria do not address duration or extreme conditions.

Fish and benthic macroinvertebrate populations are especially sensitive to the direct and indirect effects of sedimentation and turbidity. While in the water column, suspended sediments can damage the health of fish and sweep-out benthic macroinvertebrates. When suspended sediments settle, they can suffocate salmonid eggs in redds and smother macroinvertebrates. Channel filling eliminates pool habitats, and shallow depths are prone to quicker heating to lethal temperatures. High turbidities can cause behavioral changes in fish communities. Some toxic and oxygen-demanding chemicals are adsorbed to settled sediment where they are available to harm organisms.

Some of the fish communities in the Hangman Creek watershed include trout species sensitive to elevated turbidity and suspended sediment. As described earlier in the Aquatic Life Uses section, rainbow trout, native redband trout, cutthroat trout, and eastern brook trout have been found in several tributaries in the watershed (Lee, 2005; Peters, Kinkead, and Stanger, 2003; McLellan, 2005). California Creek, Marshall Creek, and a few creeks in the upper watershed on the Coeur d'Alene Reservation have survived remnants of a once larger redband trout distribution in the watershed.

Trout have not been found in the tributaries and reaches of the mainstem that were 303(d) listed (Table 21). The Coeur d'Alene Tribe water quality assessment listed high suspended sediment concentrations as one of several water quality problems limiting trout production in Little Hangman Creek (Peters, Kinkead, and Stanger, 2003). Lee (2005) and McLellan (2005) suggest that extensive habitat degradation from sedimentation and poor riparian cover limit trout production in Rock Creek and throughout the watershed.

Benthic macroinvertebrate evaluations conducted by SCCD in 1995-1997 (Celto, Fore, and Cather, 1998) and by Ecology in 2003 (Ecology, 2005) identified several reaches with benthic community impairment. The SCCD (1998) identified Hangman Creek at Roberts Road and at Bradshaw Road as having the most impaired habitat and macroinvertebrate communities among six sites evaluated. Ecology (2007) data (Table 22) had similar macroinvertebrate scores, except the Ecology scores for the site at the mouth of Hangman Creek were lower than given in the assessment by SCCD (1998).

There are many concerns about wide-spread problems with suspended sediments and turbidity in the Hangman Creek watershed:

- Suspended sediment can transport phosphorus and other pollutants through the watershed.
- Suspended sediment and turbidity degrade aquatic communities and their habitats.
- Channel-filling and bank erosion in Hangman Creek are problems aggravated by increased suspended sediment transport and deposition.
- Spokane River dams are experiencing accelerated pool sedimentation downstream caused by Hangman Creek sediment loads.
- Sediments export pollutants from Hangman Creek to the Spokane River and Lake Spokane.

Table 22. Benthic macroinvertebrate sample scores from seven sites in the Hangman Creek watershed collected August 11–14, 2003 (Ecology, 2005).

Site	Overall Score	Long-Lived Score	EPT Score
Hangman Creek at mouth	24	3.3	10.8
Hangman Creek at Bradshaw Road	26	3.3	12.5
Hangman Creek at Tekoa	20	3.0	9.3
Marshall Creek	32	5.5	16.5
California Creek near mouth	36	5.8	19
Rock Creek at Jackson Road	26	2.3	10.3
Rattler Run near mouth	28	3.0	9.3

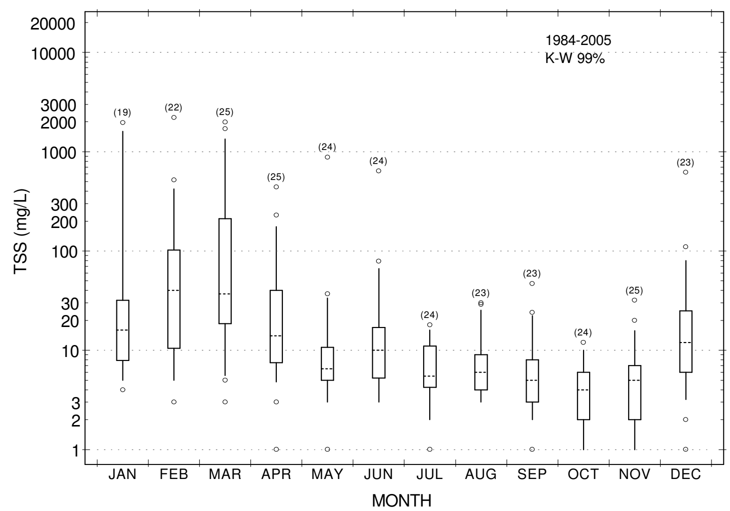
Overall Score = sum of ten indices: > 34 good, 23 – 33 fair, < 22 poor
Long-lived score = average number of long-lived taxa
EPT Score = average number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera

Critical conditions

Turbidity and TSS are somewhat correlated with stream discharge. Storm events any time of the year with a rapid rise in stage height generate elevated levels of turbidity and suspended sediment. This was observed over the 1998-2001 USGS and SCCD cooperative monitoring period during several events (SCCD, 2002), and during the 2003-2004 monitoring surveys (SCCD, 2005).

Elevated suspended sediment and turbidity are most pronounced during January through March (Figure 28). A previous evaluation of total sediment transport came to the same conclusion (USGS and SCCD, 2002). These months also have the highest mean monthly flow discharge (Table 7). During this period, conventionally tilled fields are susceptible to erosion by rains falling on partially frozen and snow-covered soils with little vegetative crop residue to hold soil in place (SCCD, 2002). The data also show that elevated TSS and turbidity values can occur through June in some years.

Wastewater treatment plants are not considered significant sources of turbidity and solids in Hangman Creek. Current municipal NPDES permits limit TSS to loads far lower than are of concern in the watershed – point sources have annual averages of pounds/day compared to tons/day from some nonpoint sources during runoff events. Municipal and construction stormwater sources are potential sources of TSS during storm events, however, municipal stormwater permits set high removal standards for TSS, and construction stormwater permits are written to limit turbidity levels to less than 25 NTUs.



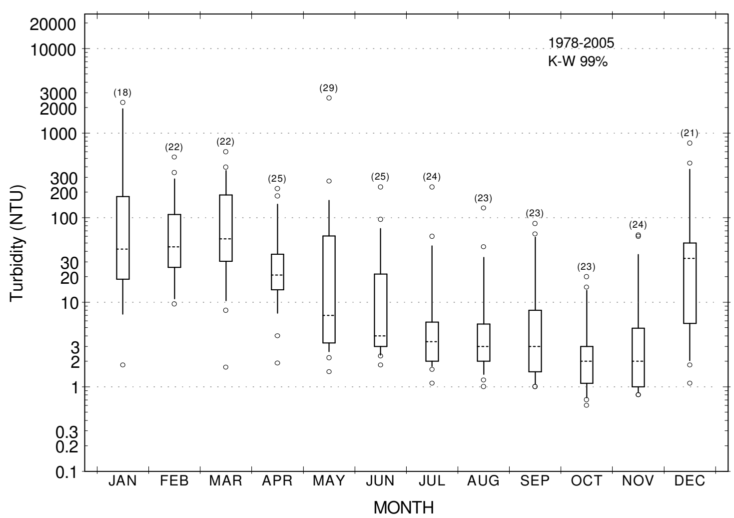


Figure 28. Total suspended solids (TSS) and turbidity statistics from monthly samples collected at the mouth of Hangman Creek from 1984 to 2002. The box plots show the 90th and 75th percentile, median, 25th and 10th percentile. In parentheses are the sample counts used to generate the statistics.

The transport of sediment and other materials from the upper watershed to the mouth of Hangman Creek can take days to years depending on the hydrologic characteristic of the season. The severity of turbidity and suspended sediment events on different parts of the watershed can vary from year to year because of varying run-off event frequencies and watershed upland conditions (e.g., exposed soils and streambank conditions). It is not reasonable to define a single critical condition for the entire watershed. Therefore, a multi-year analysis is more appropriate.

A multi-season, multi-year analysis also makes sense from a biological viewpoint. Sensitive life-stages of fish and benthic macroinvertebrates are present at various times of the year. For example, redband trout are thought to spawn as streamflows begin to decrease any time from March through June. Eastern brook trout spawn in the fall. Benthic macroinvertebrates develop over the year where they can be exposed to poor water quality conditions at all times.

Organisms and their habitat are damaged by both the intensity and duration of suspended sediment/turbidity (Newcombe and McDonald, 1998; Bash, Berman, and Bolton, 2001). The primary approach of the TMDL will be to limit the intensity and duration of turbidity concentrations and suspended sediment concentrations/loads. This approach makes use of the narrative standard applied to total suspended sediment loads that directly impact the designated and existing uses of the system. Salmonid spawning and emergence in the late-spring through fall is the most critical time of the year to protect. However, this approach will reduce the erosion rate in the watershed throughout the year, lower the sediment and associated pollutant export to the Spokane River, and provide full protection for the existing and designated uses in the Hangman Creek system.

Analytical framework

Data collected by Ecology, the SCCD, and the USGS were used to evaluate the relationships between streamflow, TSS, and turbidity in Hangman Creek. Movement of suspended sediments or TSS is often associated with rapid streamflow changes. The suspended sediment loads are the result of soil, sediment, or organic solids particles carried from varying upland land uses, streambanks conditions, and stream bottom accumulations. Relevant data for local landscape and stream channel features were also collected. Although not considered in this assessment, fine sediments can also be blown by winds into waterways and drainage routes.

Turbidity is regulated under the Washington State water quality standards with specific criteria; suspended sediments are not. But turbidity loads cannot be calculated since turbidity is a measure of visibility through water, not a concentration of something in the water. Therefore, this TMDL will set allocations for TSS to address the impairment of the narrative criteria.

Turbidity and suspended solids are often correlated in the water column since more solids will scatter more light, reduce visibility, and increase turbidity. The Hangman Creek data show some challenges for using turbidity to estimate TSS (Figure 29). Turbidity measurements rely on particles remaining in solution. If the TSS particles sink or float, the correlation between the turbidity and suspended solids becomes more variable. This especially occurs during high streamflow events when heavier sands and lighter organic debris are swept in the current.

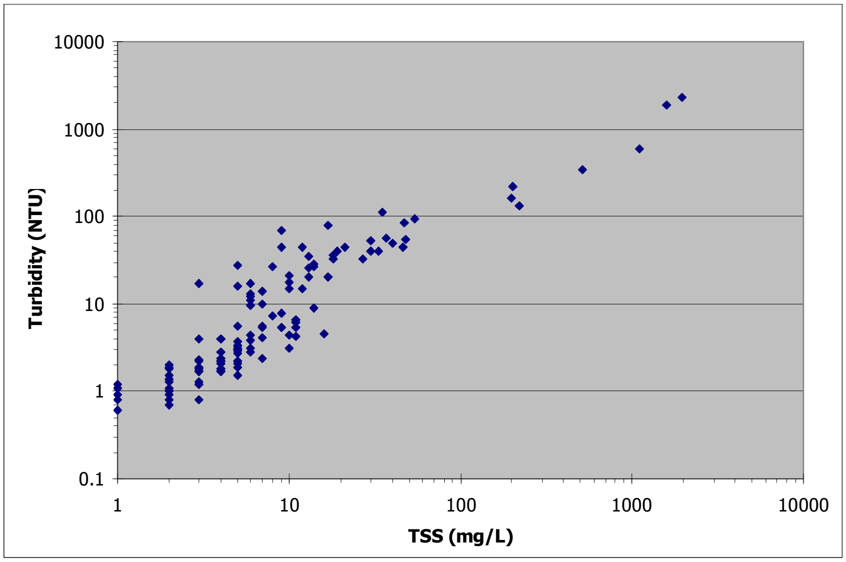


Figure 29. Total suspended solids (TSS) concentrations compared to turbidity results in monthly samples collected at the mouth of Hangman Creek (56A070) from October 1994 to September 2005.

The turbidity criteria are also difficult to establish for a site in a watershed when nonpoint sources and natural events are the dominant factors of interest. A reference turbidity value is required to measure against turbidity increases at the point of interest. In a watershed with several soil and land use types, an adequate reference site, or set of reference sites, is difficult to obtain. Therefore this TMDL is based on reductions of suspended sediment.

However, the TSS method also uses only a portion of the entire sample collected. Heavier and lighter materials can be left out of the portion of the sample that is drawn and analyzed Therefore, TSS values can underestimate the suspended sediment load especially during high flow conditions when larger particles are present in the water column.

Several tools were used to examine the suspended sediment and turbidity data from the Hangman Creek watershed to evaluate different parts of the problem and to compare outcomes in the same area. Statistical tests were run using WQHYDRO® (Aroner, 2007) and Microsoft® Office Excel (2003) software. A multiple regression analyses method by Cohn (1988) was used with SYSTAT® software. The WARMF model was run with software provided through the EPA Office of Environmental Research and originally developed by the Systech Corporation (Systech, 2001).

The multiple regression model and the WARMF landscape model are not meant to completely match, but are meant to be complementary. The Cohn (1988) multiple regression model is a statistical tool that is only appropriate where continuous streamflow can be correlated with a fairly large water quality dataset such as at the mouth of Hangman Creek. The multiple regression model is important to address the cumulative suspended solids loading from Hangman Creek to the Spokane River. WARMF relies on soil, land use, climate, and land cover data to simulate processes in the watershed that affect suspended sediment generation and transport. It provides a relative estimate of suspended sediment sources loading in Hangman Creek catchments that contribute loads to various portions of the creek and cumulatively to the mouth.

Cohn's (1988) log-linear multiple regression model can accurately simulate most of the seasonal variability in the long-term suspended sediment loads at the mouth of Hangman Creek. The model provides daily estimates of suspended sediment based on the relationship between daily average discharge data (USGS) and monthly TSS (Ecology) and suspended sediment (USGS) samples. The regression model requires estimates of several parameters: a constant, a linear and quadratic fit to the log of discharge, and sinusoidal functions to remove the effect of seasons. More details on the model are provided in Appendix C.

The WARMF model was used to evaluate the relative impact of landscape and water column TSS loads in the entire Hangman Creek watershed (Washington, Coeur d'Alene Reservation, and Idaho). The EPA Region 10 office provided a grant to perform the work. EPA, Coeur d'Alene Tribe, Ecology, and SCCD agreed that an assessment of the whole watershed was necessary to address sediment issues. The model was constructed and initially calibrated for the Hangman Creek watershed by the Cadmus Group and CDM (2007).

CDM (2007) divided the watershed into 36 catchments in the model to characterize hydrology and pollutant delivery (Figure 30). Local soils, land uses, climate, and geographic features of the land and stream channels are generalized within each of the 36 catchments of the WARMF model. The average size of the catchments is 12,000 acres with a range of 576 acres to 27,785 acres. Model outputs are calculated daily based on rainfall, temperature, and point source inputs. Descriptions of the model and coefficients of interest are provided on the Hangman Creek TMDL website at www.ecy.wa.gov/programs/wq/tmdl/hangman_cr/technical.html

While working on the WARMF model, it became apparent to Ecology and the Hangman Creek Advisory Committee that not all suspended sediment mechanisms of generation and transport are adequately described in local datasets. Upland soil and streambank erosion rates all require more investigation and analysis. Local basic data collection needs to be conducted to better calibrate WARMF or any future landscape model.

The goal of the framework is to estimate the suspended sediment/TSS reductions that can be expected after a progressive set of BMPs are in place. The reductions will be estimated for the mouth of Hangman Creek, for 303(d) sites, and for other sub-watershed areas in the entire watershed. The sediment and TSS reductions will be expressed as annual averages or the annual average over the 1998–2005 simulation period.

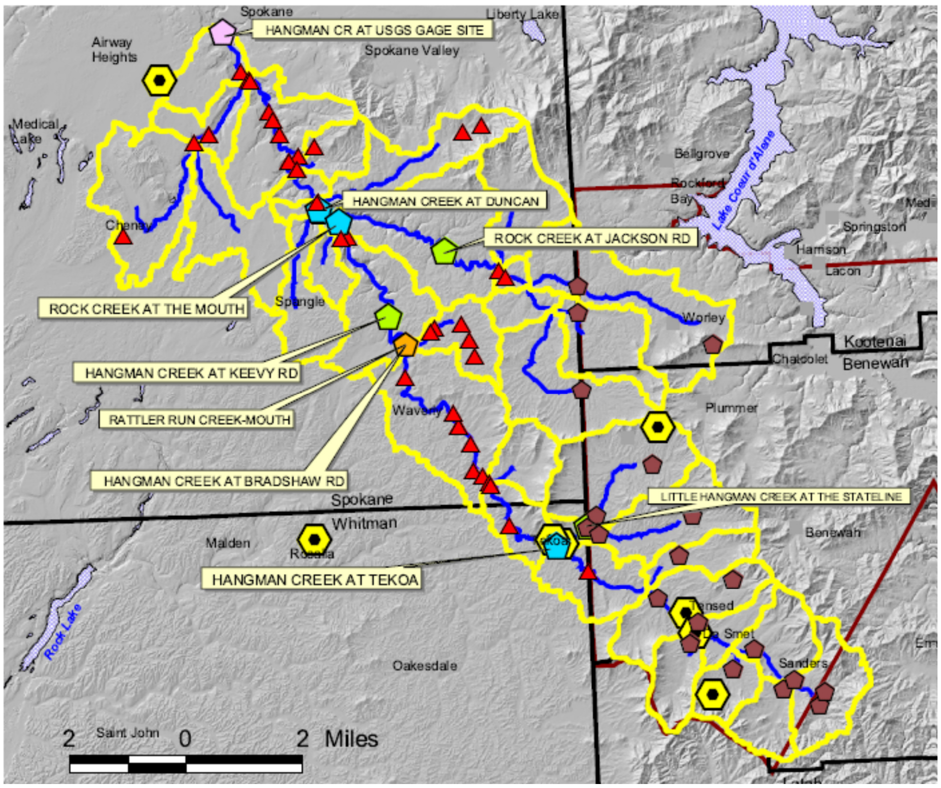


Figure 30. Delineated catchments and stream layout for the Hangman Creek Watershed Analysis Risk Management Framework (WARMF) model (Cadmus Group and CDM, 2007).

The model output at the mouth of Hangman Creek can be used to evaluate whether the BMPs reduce the duration and intensity of elevated suspended sediment, and thus can be used as an estimation of the BMPs that would be required to fully protect the designated and existing uses from the scour, smothering, and other effects associated with total suspended solids loads. Newcombe and Jensen (1996) developed formulae to describe the severity of impacts to various fish populations from suspended sediment. Ecology is using this scoring tool to determine the level of control needed to fully protect the uses. The severity score values and descriptions are shown in Table 23. The severity score for juvenile and adult salmonids, including trout, is calculated from the following formula:

$$\text{Severity score} = 1.0642 + 0.6068(\log_e \text{Hours of exposure}) + 0.7384(\log_e \text{TSS mg/L})$$

For example, an event with an average TSS concentration of 360 mg/L for nine days (216 hours) scores a 9; most likely resulting in lasting damage to a resident fish population. An event with an average TSS concentration of 16 mg/L for 108 days (5760 hours) scores an 8, whereas if the same 16 mg/L lasted only 2 days, the score is a 5. Both of these latter conditions are in the sub-lethal range, but trout populations exposed to two days of 16 mg/L TSS would probably recover and be in healthy conditions compared to a population exposed long-term to the same concentration.

Coeur d'Alene Tribe researchers used the severity scores for evaluating fisheries in the Hangman watershed in 2001 to 2002 (Peters, Kinkead, and Stanger, 2003). They noted that Hangman Creek tributaries with high severity scores had poor fish community structure, low trout abundance, and poor habitat conditions. At least five sites on the tribal reservation had severity scores of 9. They also determined the severity score for Hangman Creek at State Line (Road) was 8 based on TSS levels of >5 mg/L for most of the year.

Table 23. Newcombe and Jensen (1996) scale of severity of ill effects to fish associated with excess suspended sediment.

Severity Scale	Description of Effect
No Effect	
0	No behavioral effects
Behavioral Effects	
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
Sub-lethal Effects	
4	Short-term reduction in feeding rates or feeding success
5	Minor physiological stress; increased coughing, increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation; impaired homing
8	Indications of major physiological stress; long-term
Lethal and Paralethal Effects	
9	Reduced growth rate; delayed hatching; reduced fish density
10	0 – 20% mortality; increased predation; moderate to severe habitat degradation
11	>20 – 40% mortality
12	>40 – 60% mortality
13	>60 – 80% mortality
14	>80 – 100% mortality

The severity score used by Ecology to estimate full protection for the designated and existing uses in the watershed is the range of 0-4. The score of 4 represents a short-term reduction in feeding rate or feeding success, which should only be present for short periods. The range should be present within the watershed throughout the year, found in refugia during high flow events (times of the year when spawning and incubation does not occur) and in the mainstreams of the reaches during the period of the year when spawning and incubation occur.

This TMDL is the first to use the narrative standard to address total suspended solids. In developing this approach Ecology took into consideration the temporal relationships between flow, TSS, and life cycles of the trout present in the system. This relationship was overlaid onto the reductions in TSS and development of refugia resulting from BMPs, allowing an estimate of a protective TSS score to be present within the watershed, as needed by the biota, in a manner consistent with a naturally functioning system.

Calibration of models

The long-term monthly TSS data record collected by Ecology at the mouth of Hangman Creek (station 56A070) provides a calibration dataset for the Hangman Creek models. However, the dataset has some limitations:

- Samples collected by Ecology at the site are not laterally or transversely integrated, so they may under-represent the true average suspended solids concentration and load.
- It does not record rapid changes in discharge and TSS concentrations within a day.
- Watershed land uses, and crop rotation and management patterns, have changed. So, consistent statistical relationships between season, streamflow, and TSS cannot be assumed.

The multiple regression equation was applied to the monthly TSS concentrations collected by Ecology, and to the mean daily streamflow reported by USGS at the mouth of Hangman Creek. The Nash-Sutcliffe coefficient was used to evaluate the model fit to observed data. The model fit the observed TSS/suspended sediment load estimate very well, even when the USGS suspended sediment data are added (Figure 31). The Nash-Sutcliffe coefficient of observed Ecology data and model output is 0.8, where 1.0 is ideal.

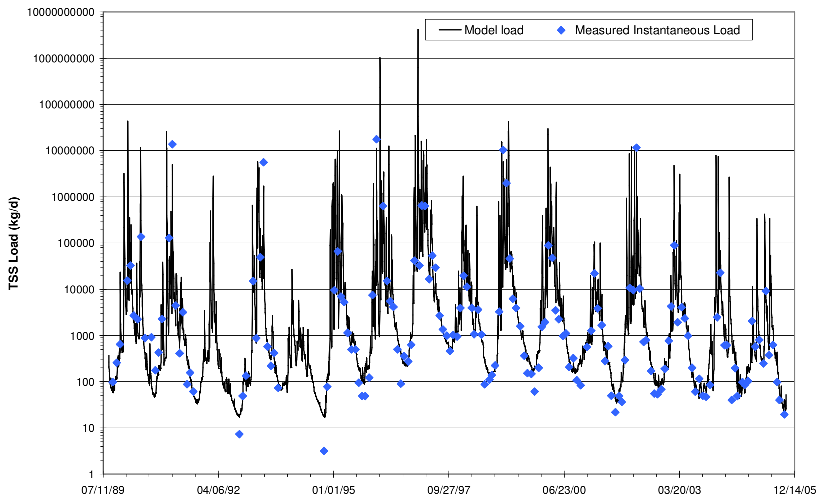


Figure 31. Total suspended solids (TSS) estimated loads in kilograms per day (kg/d) from the multiple regression model compared to TSS estimated loads based on monthly TSS samples and instantaneous discharge measurements collected at the mouth of Hangman Creek (Ecology station 56A070).

The severity score formula was applied to the TSS concentrations generated by the multiple regression model at the mouth of Hangman Creek (Figure 32). The scores indicate trout species often are exposed to lethal and sub-lethal levels of suspended sediments at the mouth of Hangman Creek. The problems are most severe during the winter and early spring, but sub-lethal exposures often occur through the late spring into mid-summer and can start again in early fall. As mentioned earlier, redband trout would be expected to find refuge in side channels and tributaries during the winter and early spring, but migration and spawning usually start mid-spring when streamflows begin to drop. The high severity events occurring during this latter period are the greatest impediment to maintaining a healthy fish community in the watershed.

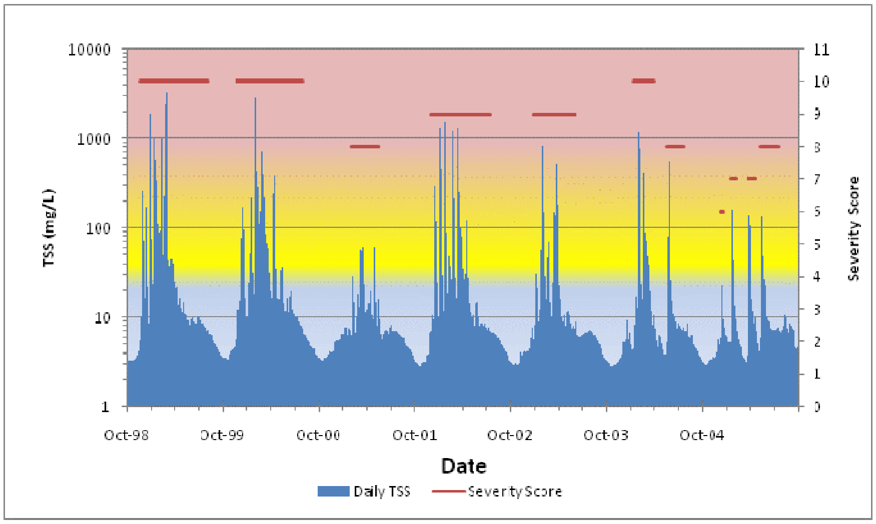


Figure 32. Period of sub-lethal (severity score 4–8) and lethal (severity score ≥9) suspended sediment conditions to trout species at the mouth of Hangman Creek. Suspended sediment concentrations are estimated from the multiple regression model, and severity scores are calculated from the formula by Newcombe and Jensen (1996).

The WARMF landscape model also was calibrated to the long-term USGS streamflow data at the mouth of Hangman Creek (USGS 12424003) from October 1998 through September 2005, and to several short-term SCCD gage sites in the watershed from 1999 or 2000 to 2005:

- Hangman Creek at Duncan
- Rock Creek
- Rattler Run
- Hangman Creek at Bradshaw Road
- Hangman Creek at Tekoa

Climate is an important driver for the model. Accurate rainfall and temperature data are necessary to generate the streamflow quantities in the catchments. Unfortunately, the two meteorological stations in Washington with nearly complete data sets are outside the western edge of the Hangman Creek watershed at the Spokane Airport and Rosalia. Incomplete records are available for stations in the upper watershed at Plummer and near Tensed, Idaho. A great number of missing records for these latter two stations had to be estimated to run the model. Future modeling work would be enhanced with more reliable data specifically targeted within the watershed.

The initial hydrological calibration of the model by Cadmus Group and CDM (2007) was good considering the available data: higher flows in the watershed were simulated quite well, but the model over-estimated the low-flow period. The Nash-Sutcliffe coefficient for flows at the mouth of Hangman Creek was 0.68 (Cadmus Group and CDM, 2007). After the calibrated model was delivered by the consultants, additional data were collected to refine streamflow and water quality simulations.

Refinements to the model were made to better simulate streamflow conditions:

- More SCCD rating curves were used in the model for tributaries and mainstem locations.
- Catchment widths in the Rock Creek sub-watershed were adjusted to prevent unrealistic runoff and erosion.
- Some cropping factors for various land uses were found to be outside the range of recommended values in the initial calibration, so they were adjusted accordingly.
- The discharge from the Rockford wastewater treatment plant (WWTP) was changed from continuous to seasonal (February through April). Seasonal discharges from the Freeman School District WWTP were added.
- The Cheney WWTP was modified from continuous discharge directly to Minnie Creek, to a large on-site system to simulate the current wetland treatment system without a surface discharge.
- Ten percent of the assigned conventional agricultural land use was shifted into direct seed/ conservation agriculture with a different set of system coefficient parameters.

The final version of the WARMF model by Ecology brought the water balance of the low-flow period into better calibration (Figure 33). The Nash-Sutcliffe coefficient for 56A070 flows at the mouth of Hangman was 0.75, and was 0.58 for all USGS flows. Cumulative runoff volume plots demonstrated that the model was capable of simulating total annual outflow over several years (Figure 34). The model still over-predicted run-off in the low-flow period, especially during drier years (e.g., 2001, 2003, and 2005). It slightly under-predicted the high-flow period and missed the peak flow timing. Frequent spiking in the simulated flows compared to the observed data needs to be remedied in future model refinements.

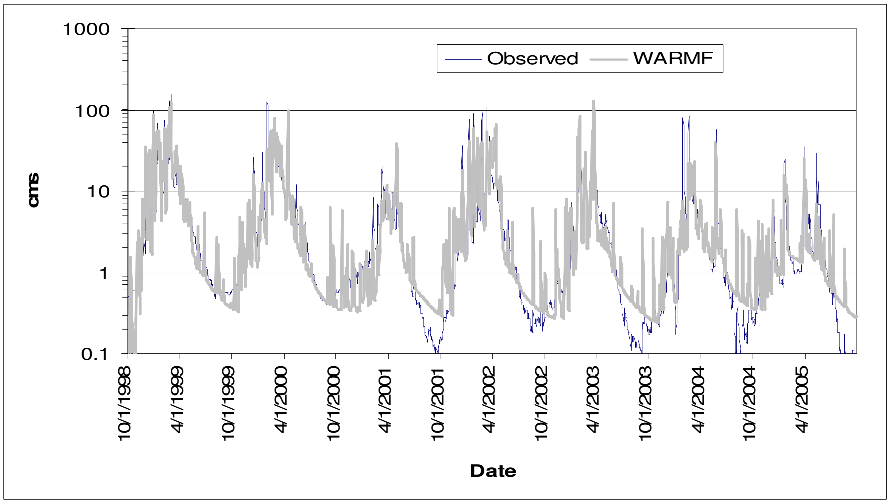


Figure 33. WARMF model of Hangman Creek (Cadmus and CDM, 2007) hydrological calibration output compared to observed streamflow data for 1998-2005: daily streamflow simulation. Values are in cubic meters per second (cms).

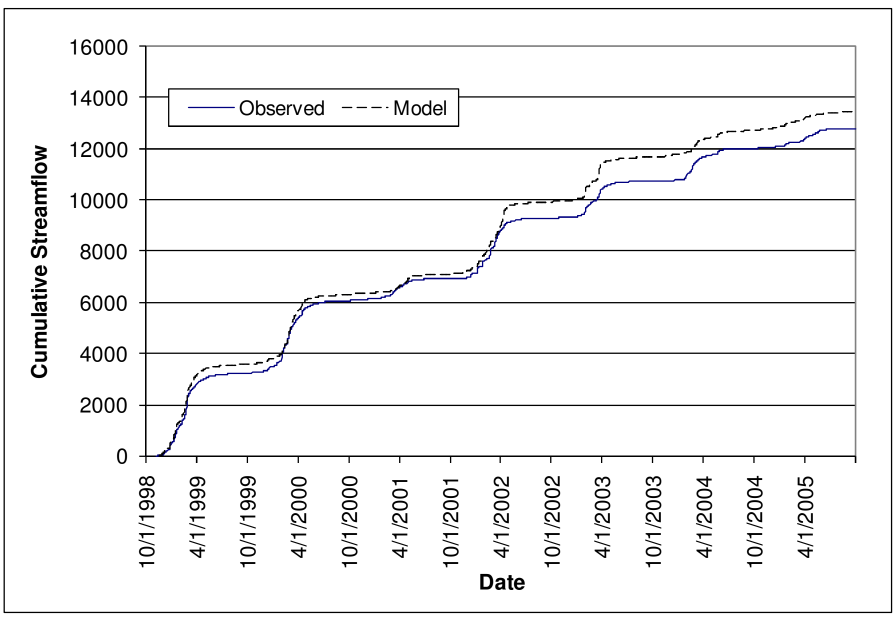


Figure 34. WARMF model of Hangman Creek (Cadmus and CDM, 2007) hydrological calibration output compared to observed streamflow data for 1998-2005: cumulative flow volume.

The WARMF model was calibrated to the USGS and SCCD suspended sediment data collected at the mouth of Hangman Creek from 1998 to 2001, in addition to the Ecology monthly TSS data. As mentioned earlier, these data are not quite equivalent, and combining them into one database may increase model variability. In addition, SCCD, Coeur d'Alene Tribe, and Ecology water quality data from various sites throughout the watershed were also used. The intermittent and small water quality data sets at most of these upstream sites and point sources meant that calibration was not highly accurate for many areas of the watershed.

The WARMF model suspended sediment output (Figure 35) shows some of the same characteristics as the discharge output (Figures 33 and 34). Since the hydrology simulation tended to overestimate low streamflows and create high streamflow spikes, suspended sediment loads show those same characteristics. The sediment load estimates become more variable because of the uncertainty in erosion rates and transport coefficients.

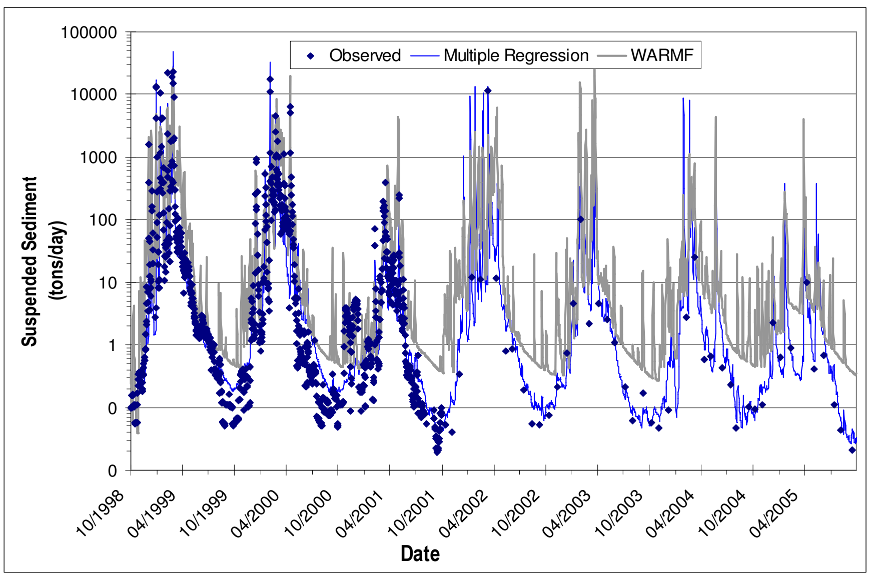


Figure 35. A comparison of suspended sediment loads from WARMF and the multiple-regression models output, and observed instantaneous loads for the mouth of Hangman Creek.

The overall annual load estimated by the WARMF model is greater than calculated by the SCCD (2002) or the multiple regression model for the years 1998 to 2005 (Table 24). Higher streamflow years such as 1999, 2000, and 2002 are simulated a little better than low streamflow years. Higher flow months match a bit better than transition (fall, late spring) or low streamflow months, but the relationship between discharge and TSS is different even at flows greater than 100 cfs (2.83 cms) Figure 36. The WARMF model is biased high relative to the multiple regression model and has a greater variability.

Table 24. Three estimates of annual suspended sediment load compared to annual average discharge at the mouth of Hangman Creek for the water years 1998-2005.

Water Year	USGS (tons)	Multiple Regression Model (tons)	WARMF Model (tons)	Annual Average Discharge (cfs)
1999	175,000	188,252	190,787	315
2000	83,000	90,677	139,855	273
2001	3,430	1,604	19,824	84
2002	-	73,770	72,687	229
2003	-	16,503	180,869	139
2004	-	30,605	19,543	124
2005	-	2,832	13,147	73.5

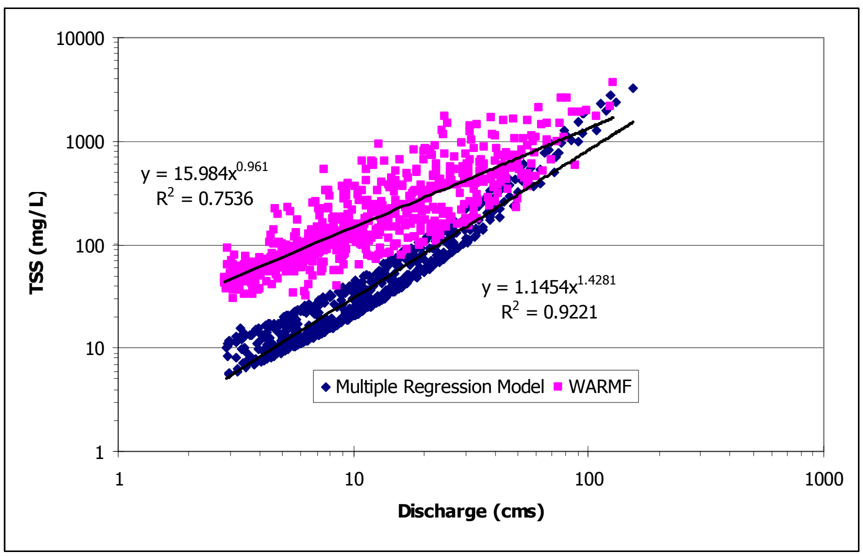


Figure 36. Hangman Creek at the mouth: correlation between discharge and suspended sediment concentration estimated by two models for discharges greater than 2.83 cubic meters/second (cms) or 100 cubic feet/second (cfs).

Loading capacity

It is difficult to develop an estimate of the 'natural or background' suspended sediment components for loading capacities for Hangman Creek and its tributaries. The watershed encompasses four Level IV Ecoregions with different geological and vegetation characteristics. The morphology of the watershed is a result of centuries of erosive forces on natural sources of sediment. Added to these natural processes are human practices over the past 150 years that have accelerated some forms of sediment transport.

Elevated suspended sediment and turbidity events occur in all watersheds. The duration and intensity of Hangman Creek events have both natural and human-caused sources. By reducing the duration and frequency of elevated turbidity and TSS events through erosion control measures, a 'flattening' of the annual average discharge to sediment delivery relationship curve should occur. Benthic macroinvertebrate and aquatic habitat metrics should also gradually improve in impaired reaches, and the frequency and duration of lethal and sub-lethal suspended sediment severity scores for effects on trout should also be reduced.

The Hangman Creek Advisory Committee questioned if pollutant load capacities should be predicted from a pristine or natural state scenario that would serve to estimate a loading capacity. The following points were made:

- The construction of Highway 195 drastically changed the hydrology of lower Hangman Creek by cutting off several meanders and channelizing sections.
- Substantial development in the lower watershed prevents floodplain migration.
- In the upper watershed, more than 100 years of agriculture has resulted in significant stream channel straightening, wetland reduction, and removal of forest and prairie vegetation.
- No reference sub-watersheds are available for each of the diverse Ecoregions represented in the watershed.

Some of the measures necessary to restore Hangman Creek's historic hydrology and upland character will not be easy to accomplish. These would include relocating the highway and changing the development pattern of the lower watershed. However, there may be a suite of actions that, when fully implemented, could result in full protection of the designated uses in Hangman Creek.

The suite of actions identified by the Advisory committee is:

- Convert 60% of the agriculture in the watershed to direct seed or conservation practices.
- Have riparian buffers established all along the mainstem channels and tributaries.
- Reduce the streambank erosion in the upper watershed (above Fairfield) by 50% and erosion in the lower watershed with Lake Missoula flood sediments by 10%.
- Increase forest cover in catchments above Rockford and Tensed by 50%.
- Limit residential growth to levels below 10% in the lower watershed (catchments 3, 4, 7, 9 and 10).
- Repair failing residential on-site septic systems.

The calibrated WARMF model was used to estimate the effect of this set of BMPs to reduce suspended sediment in Hangman Creek (Figure 37). Although the WARMF model calibration of observed sediment data is not as closely matched as the multiple regression model, the results provide important insight into the response of sediment sources in the watershed to actions. This set of BMPs *was used to estimate the reference turbidity, suspended sediment loading conditions, and the loading capacities for Hangman Creek and various areas in the watershed. These BMPs represent a combination of actions that are estimated to provide full protection for the uses in the system.*

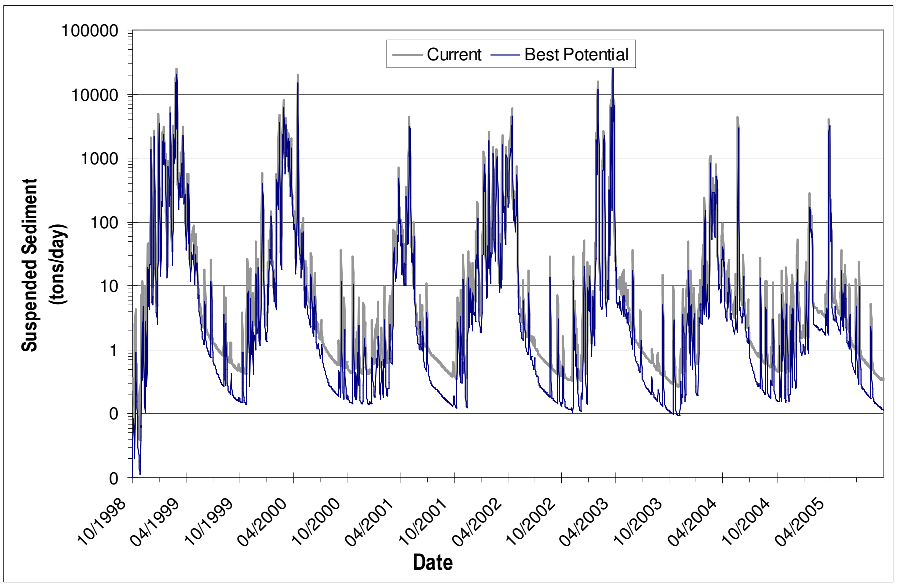


Figure 37. Estimated daily average suspended sediment loads at the mouth of Hangman Creek based on WARMF model scenarios of current conditions and estimated full protection conditions.

At the mouth of Hangman Creek, the estimated annual suspended sediment loads under the estimated full protection scenario are 20% to 30% lower than the simulated current condition (Table 25). The reductions estimated by the WARMF simulations are applied to the multiple regression model load results in Table 23 to demonstrate the estimated cumulative watershed load reductions from Hangman Creek to the Spokane River. Figure 38 estimates how the BMP-based scenario will 'flatten' the sediment rating curve at the mouth of Hangman Creek. The curve could be used to evaluate the TMDL effectiveness in the future.

As would be expected, examination of the model output suggests the annual variability in effective sediment load reductions is induced both by the intensity and frequency of runoff events. A year with several flood events generates more streambank erosion in the lower reaches that is not easily remedied even under the estimated full protection scenario actions. On the other hand, sediment reductions are greater in years with a series of moderately-intense storm events in winter and early spring when conservation methods and buffers[3] are in place compared to the current presence of bare agricultural soils.

Table 25. Suspended sediment reduction predicted from WARMF model scenario estimates for annual suspended sediment loading from Hangman Creek to the Spokane River.

Water Year	Multiple Regression Model (tons/year)	Estimated Reduction	Estimated Load Capacity (tons/year)
1999	188,252	22%	147,206
2000	90,677	25%	67,872
2001	1,604	31%	1,109
2002	73,770	28%	53,326
2003	16,503	21%	13,101
2004	30,605	32%	20,846
2005	2,832	29%	2,022

In Table 25, the WARMF model current and estimated full protection scenario results were compared. The percent reduction in suspended sediment loading is applied to the regression model estimates in Table 24 to provide an estimate of the annual load capacity.

[3] The buffer zone option of the WARMF model did not appear to function. Therefore, sediment reductions may be better than predicted for the estimated full protection scenario.

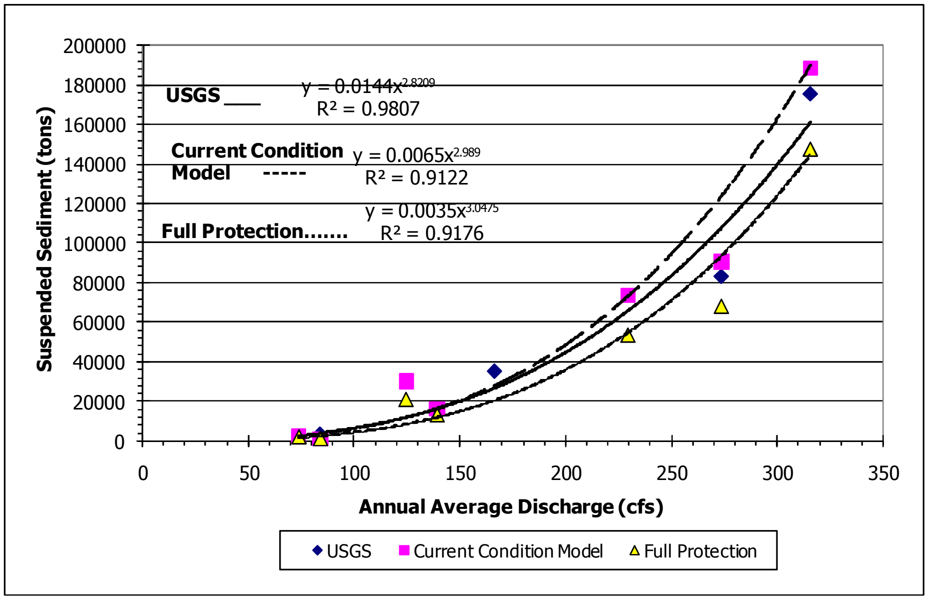


Figure 38. The estimated change in the sediment rating curve at the mouth of Hangman Creek after estimated full protection scenario improvements are implemented in the watershed. The current condition model estimate and USGS study data (SCCD, 2002) are also shown.

The results of the estimated full protection scenario were used to estimate the daily suspended solids concentration at the mouth of Hangman Creek. The severity of impacts to various fish populations from suspended sediment scores were calculated from the Newcombe and Jensen (1996) formula and compared to the current conditions estimate (Figure 39). Significant improvements were predicted. The estimated full protection scenario established throughout the watershed was successful in either lowering or shortening the duration of the highest lethal and sub-lethal conditions scores. Most importantly, lethal and sub-lethal conditions in late spring and summer and in the early fall were eliminated. These are the critical spawning and emergence periods for redband and other trout that require the most protection. Low severity score areas during high flow events will be provided within refugia. In this watershed resident fish currently utilize tributaries and some areas of the mainstem as refugia. Riparian buffers, streambank restoration and stabilization and other sediment reductions will continue to improve and increase the refugia. The predicted seasonal and annual TSS reductions in the Hangman Creek watershed will protect sensitive species.

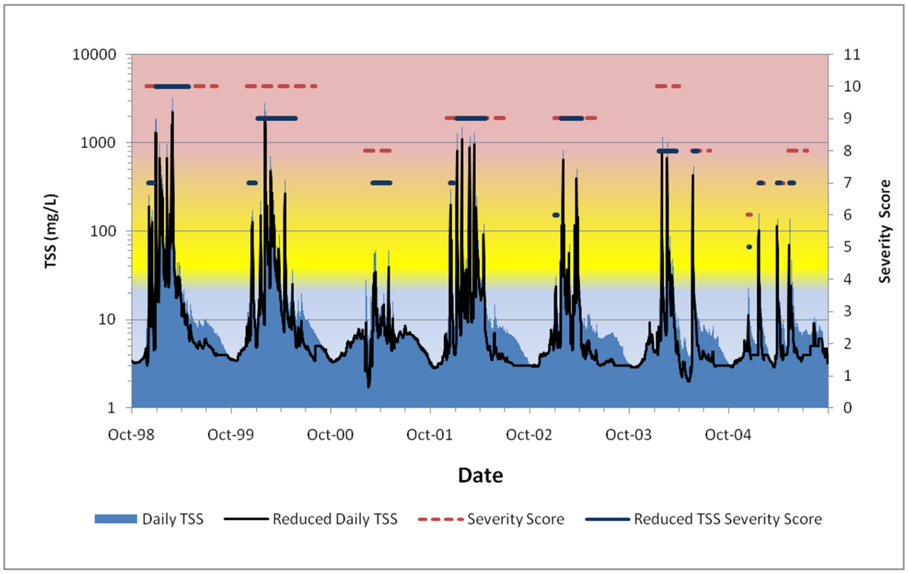


Figure 39. A comparison of estimated current and estimated full protection (reduced) scenario suspended sediment conditions for trout species at the mouth of Hangman Creek including lethal and sub-lethal severity scores calculated from the formula by Newcombe and Jensen (1996).

In a similar manner, suspended sediment loading capacities for various tributary and mainstem reaches of Hangman Creek were determined by comparing the WARMF model current condition and estimated full protection scenario results. Since sites throughout the watershed do not have long-term water quality records to take advantage of the multiple regression model, the average loads over the entire 1998–2004 simulation period were compared instead of individual annual sediment loads. Unfortunately, for lack of continuous datasets, a set of fish impact severity scores for current and post-estimated-full-potential conditions could not be constructed either. Effectiveness can only be measured when biological or water quality monitoring is conducted before and after BMPs are implemented.

The range of estimated sediment reduction expected at the 303(d) listed reaches in the watershed after BMP implementation was from 15 to 19% (Table 26). These reductions represent the average annual suspended sediment reduction over seven water years. The year-to-year variability would be similar to what is shown in Table 25 for the mouth of Hangman Creek. The BMPs are especially effective in shortening the intensity and duration of lethal and sub-lethal events in the mid-to-late spring and early fall seasons. Winter and early spring peak TSS concentrations throughout the watershed would be reduced as well so fish seeking refuge in side channels and tributaries would also be protected. The estimated TSS load reductions of the reaches are expected to be even greater once the buffer zone option of the WARMF model can be used in the model simulation.

Table 26. WARMF model simulation results for overall suspended sediment reductions and source reductions estimated at 303(d) sites in the Hangman Creek watershed.

Site	Overall Reduction	Primary Sources	Reduction to Sources
Hangman Creek at Bradshaw Road	19%	Conventional Agriculture	56%
		Streambanks	74%
		Rangelands	31%
Little Hangman Creek	15%	Conventional Agriculture	55%
Rattler Run Creek	15%	Conventional Agriculture	54%
Rock Creek at Jackson Road	17%	Conventional Agriculture	55%
		Rangelands	18%
		Streambanks	90%

The TSS reductions predicted by the estimated full protection scenario will improve aquatic community health and diversity including salmonid fisheries in the 303(d) listed tributary and mainstem areas. Recent assessments of these areas gave extremely low habitat and fish abundance scores (Lee, 2005: Peters, Kinkead, and Stanger, 2003; McLellan, 2005; Ecology, 2005; Celto, Fore, and Cather, 1998). As with the evaluation of TSS severity events at the mouth of Hangman Creek (Figure 39), the predicted TSS reductions in the 303(d) areas are especially effective in the critical late spring, early summer, and fall that are important for sensitive life stages. Rock Creek, Little Hangman Creek, and Rattler Run are tributaries with spawning potential if habitat and other water quality restoration accompany TSS reductions.

The relative difference between the current and estimated full protection scenarios for the 303(d) and other areas of the watershed can help focus implementation resources and expectations. Of course habitat and aquatic community enhancements will not come with just erosion control measures to reduce suspended sediment loads. Habitat restoration, reducing instream temperatures, and preventing other forms of contamination need to occur as well. Progress toward these estimated TSS load capacities as BMPs are implemented, and the concurrent condition of the aquatic communities and habitat, will need to be monitored to verify that the model predictions of aquatic community improvements are reasonably accurate.

Load and wasteload allocations

A cooperative strategy between regulatory and governmental jurisdictions to develop and implement this TMDL yields a more comprehensive approach to controlling suspended sediment and turbidity sources in the watershed. The load and wasteload allocations established in this TMDL can only apply to pollutant loading sources located in the Hangman Creek watershed downstream of the Idaho border. Washington State cannot dictate to the Coeur d'Alene Tribe or the state of Idaho what measures they need to take in their portion of the Hangman Creek watershed, or how to allocate suspended sediment loads in their jurisdictions. However, with support and permission from the Coeur d'Alene Tribe this TMDL incorporates an assumption that sediment in upstream waters at the WA/ID border will be reduced to meet water quality standards at the border. This assumption includes no inferences regarding historic flows in the watershed. Reducing sediment loads in the upper reaches of Hangman Creek, Little Hangman

Creek, and Rock Creek depend on long-term cooperation between Washington, the Coeur d'Alene Tribe, and Idaho to implement erosion control measures.

The WARMF model results suggested major sediment erosion was generated from the same sources that have been discussed in previous reports for the watershed (SCCD, 1999; 2002; 2005a; 2005b; Peters, Kinkead, and Stanger, 2003). Conventional agricultural practices and streambank erosion are the largest sediment sources in most areas of the watershed. By implementing conservation farming methods and decreasing streambank erosion, the estimated full protection scenario loads were significantly reduced for agriculture and range lands. Additional gains are expected from developing riparian buffers which were not adequately modeled at this point.

The difference between the current and estimated full protection scenario results provides the suspended sediment targets for six sub-watersheds of Hangman Creek. Table 27 summarizes the relative distribution and the overall suspended sediment reduction for the various sub-watersheds (Figure 40) expected if the estimated full protection activities are implemented. These reductions should result in meeting the load allocations (in this case the loading capacity) shown is Table 26. Since data are inadequate to build a load duration curve or similar advanced analysis for each sub-watershed, the estimated TSS reductions are load allocations for areas within Washington. Future load analyses will need to consider the large amount of sediment stored within the watershed channels and how the transport rate of that sediment to the mouth of Hangman Creek or its major tributaries varies from year to year.

Table 27. Estimated distribution of sources generating suspended sediment in sub-watersheds of Hangman Creek under current condition WARMF model scenarios and estimated source reduction expected with implementation of the estimated full protection scenario actions. (Colors correspond to those in Figure 40)

Sub-Watershed	Current percent of sources	Estimated source reduction	Land Area percent of watershed
Upper Hangman Creek	35%	26%	20%
Little Hangman Creek and Hangman Creek from Tekoa to Bradshaw	26%	16%	19%
Hangman Creek from Bradshaw to Duncan and Rattler Run	1%	15%	8%
Rock Creek	20%	18%	27%
Marshall Creek	2%	8%	11%
Lower Hangman Creek	16%	11%	15%

The most obvious example of the problem of sediment transport rates is cross-border loading. Figure 40 shows that approximately 35% of the Hangman Creek watershed lies in catchments of Rock Creek, Little Hangman Creek, and upper Hangman Creek in the Coeur d'Alene Indian Reservation. On average, up to 60% of the water is delivered from these catchments annually.

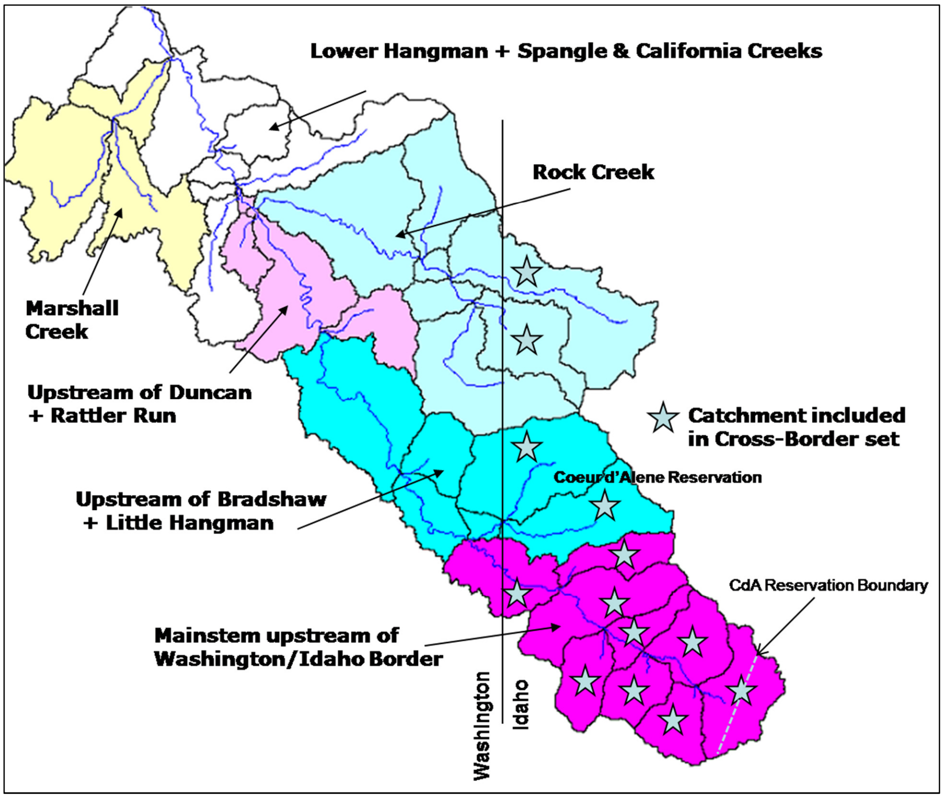


Figure 40. Hangman Creek sub-watersheds delineated in the WARMF model and catchments included in calculating cross-border loading.

As previously mentioned, the estimated full protection scenario in the WARMF model also relies on reducing sediment loads transported across the border. The TSS loads from upstream catchments will need to be managed by the Coeur d'Alene Tribe and Idaho to significantly reduce the sediment loads generated on the reservation that are carried into Washington. The WARMF model estimates of these reductions are shown in Table 28. Achieving the substantial cross-border sediment reduction target will require continued close cooperation between the states and Tribe to improve Hangman Creek, Little Hangman Creek, and Rock Creek.

Table 28. Estimated sediment reductions needed for sub-watersheds located upstream of the Washington-Idaho border. Areas are denoted in Figure 40

Sub-Watershed	Estimated Sediment Reduction Needed
Upper Hangman	23%
Little Hangman	15%
Rock Creek	19%

The WARMF model output for the 303(d) listed areas was examined. Table 26 summarizes the relative TSS reduction estimated for each area and major sources that require controls. The conversion of conventional agricultural practices to conservation practices had the largest impact because of erosion potential and upstream drainage areas affected. Streambank erosion control will be important upstream of Bradshaw Road. Rock Creek appeared to have relatively minor TSS loads generated by streambank erosion, but restoration practices may significantly reduce them further as a TSS load source.

The load allocations for both the sub-basin geographic areas and the 303(d) listed segments are summarized in Table 29. The sub-basin load allocations are estimates of the reductions from the entire land area that are necessary to meet the load allocation at the 303(d) listed stream segment.

Table 29. Total suspended solids load allocations for geographic sub-basins and 303(d) listed stream segments.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Sub-basin</th><th rowspan="2">303(d) listed segment</th><th colspan="2">Estimated % reduction</th></tr>
<tr><th>Basin</th><th>303(d)</th></tr>
<tr><td rowspan="4">Hangman Creek</td><td>Upper Hangman Creek</td><td rowspan="2">Hangman Creek at Bradshaw Road (ID 40942)</td><td>26%</td><td rowspan="2">19%</td></tr>
<tr><td>Hangman Creek from Tekoa to Bradshaw Rd</td><td>16%</td></tr>
<tr><td colspan="2">Hangman Creek from Bradshaw Rd to Duncan</td><td>15%</td><td rowspan="2">n/a</td></tr>
<tr><td colspan="2">Lower Hangman Creek</td><td>11%</td></tr>
<tr><td rowspan="4">Tributaries</td><td>Little Hangman Creek</td><td>Little Hangman Creek (ID 40940)</td><td>16%</td><td>15%</td></tr>
<tr><td>Rattler Run Creek</td><td>Rattler Run Creek (ID 40941)</td><td>15%</td><td>15%</td></tr>
<tr><td>Rock Creek</td><td>Rock Creek at Jackson Road (40943)</td><td>18%</td><td>17%</td></tr>
<tr><td colspan="2">Marshall Creek</td><td>8%</td><td>n/a</td></tr>
</table>

n/a – there are no 303(d) listed segments in this geographic area.

The current TSS NPDES permit limits for the six municipal WWTPs in the Washington portion of the watershed are adequate for TSS control in the watershed. As mentioned earlier, the combined WWTP loads are insignificant compared to the event-based loads driving field and streambank erosion. TSS wasteload allocations for Tekoa, Fairfield, Spangle, Rockford, Cheney, and Freeman School District WWTPs are equivalent to the current permit limits (Table 30).

Stormwater in areas under Phase 2 and construction permits will need to be adequately managed to reduce TSS loads to lower Hangman Creek and its tributaries. The WARMF modeling did not evaluate municipal stormwater management options. BMPs for TSS in municipal stormwater are well-known and effective. The City of Spokane, Spokane County, and WSDOT have responsibility to control stormwater in the lower reaches of Hangman Creek and Marshall Creek. WSDOT has additional responsibility to manage stormwater along other state highway crossings in the watershed.

Modeling indicated that to achieve the estimated full protection condition, an 11% reduction in sediment would be necessary in the portion of the watershed under the Stormwater Phase II NPDES permit (Table 27-Lower Hangman Creek). The TSS load from residential and commercial areas was predicted to increase 9.5% with the increased development. However, loading from residential and commercial lands in the estimated full protection scenario remained at 10% of the total TSS load, and was minor compared to streambank erosion (39%) and agricultural sources (22%).

The *Stormwater Management Manual for Eastern Washington* (Ecology, 2004) estimates that effective basic stormwater treatment BMPs remove about 80% of the TSS contained in runoff. Therefore, if these entities are in compliance with the Stormwater Phase II NPDES permit, it is anticipated they will achieve the TSS wasteload allocations established for the MS4s under this TMDL (Table 30). It should be noted that the estimated full protection scenario limited increased residential land use to less than 10% over current conditions. If residential land use exceeds the estimated full protection scenario, the wasteload allocation for this source may need to be reevaluated.

Table 30. Total suspended solids wasteload allocations for the Hangman Creek watershed.

Source	Permit Requirements		WLA
	Average Monthly Limit	Average Weekly Limit	
Tekoa WWTP	30 mg/L, 34.5 lbs/day	45 mg/L, 51.7 lbs/day	Same as existing permit
Fairfield WWTP	15 mg/L, 29.0 lbs/day	23 mg/L, 44.5 lbs/day	same
Spangle WWTP	15 mg/L, 8.5 lbs/day	23 mg/L, 12.8 lbs/day	same
Rockford WWTP	30 mg/L	45 mg/L	same
Freeman School District #358	20 mg/L, 7.2 lbs/day	30 mg/L, 10.8 lbs/day	same
Cheney WWTP	15 mg/L, 338 lbs/day	23 mg/L, 507 lbs/day	same
Industrial Facility Stormwater[1]	27 mg/L	88 mg/L[2]	same
Spokane County Stormwater	All known and reasonable treatment		80% reduction[3]
City of Spokane Stormwater	All known and reasonable treatment		80% reduction[3]
Washington Department of Transportation Stormwater	All known and reasonable treatment		80% reduction[3]
Construction Site Stormwater[4]	All necessary best management practices Turbidity Benchmark: 25NTU Background and discharge sampling required Turbidity Limit: 5 NTU over background or when background is over 50 NTU less than a 10% increase over background		same

[1]No permitted industrial facilities currently exist in the watershed.
[2] Limit is a maximum daily (not average weekly).
[3]Best management practices estimate 80% removal of TSS from stormwater sources (Ecology, 2004).
[4] Construction stormwater NPDES permit regulates turbidity but does not regulate TSS.

Conclusions and recommendations

The following conclusions and recommendations are based on this suspended sediment and turbidity TMDL evaluation:

Conclusions

- Significant cross-border TSS loads will require close cooperation with the Coeur d'Alene Tribe and Idaho to establish erosion reduction measures and improve Hangman Creek, Little Hangman Creek, and Rock Creek.
- Turbidity and suspended sediments have been longstanding problems in Hangman Creek. Naturally erosive streambanks and erosive upland soils in various parts of the watershed have been further destabilized by poor road building and agricultural practices.

- The duration and intensity of suspended sediments events have lethal or sub-lethal effects on native redband trout and other fish populations in the watershed. Events during the mid-to-late spring through the fall periods are especially damaging to aquatic communities.
- The sediment and associated turbidity have not only degraded aquatic life and habitats, but they have transported excessive amounts of sediment, nutrients, and other contaminants within Hangman Creek and to the Spokane River.
- Elevated suspended sediments and turbidity have been most pronounced in January through May, especially when conventionally tilled fields are susceptible to erosion by rains falling on partially frozen and snow-covered soils with little residue and high water erodes streambanks (SCCD, 2002).
- For this TMDL, reductions of TSS loads are an adequate surrogate for the turbidity 303(d) listings in the watershed.
- The estimated full protection scenario and associated load reductions will reduce the number, intensity and duration of TSS events. This will reduce the number of lethal and sub-lethal impacts on trout and other fish, especially during the most sensitive life-stages in the mid-to-late-spring through fall. Successful implementation of these measures will provide full protection for these sensitive life-stages and improve the fish communities in the watershed.

Recommendations

- Aquatic communities and suspended sediment loads should continue to be monitored to establish baselines and to measure success with erosion control and other improvements. Sediment rating curves should be established for key sites in the watershed.
- An estimated 20% to 30% in annual TSS loads to the Spokane River will be reduced if the estimated full protection actions are implemented. Sediment loads in 303(d) listed areas of the watershed will be reduced by a long-term annual average of 15% to 19%.
- Conversions of conventional agricultural practices to conservation practices is needed to meet the load allocations in this TMDL as this action will have the biggest impact in reducing TSS in the watershed.
- Streambank erosion control is necessary to decrease sediment generation and transport especially in the reaches between Fairfield and Tekoa.
- Municipal and construction stormwater discharges are potential sources of TSS during storm events. Spokane County, City of Spokane, and Washington State Department of Transportation have coverage under the state municipal stormwater permits in the residential growth areas in the lower reaches of Hangman Creek and Marshall Creek. Common stormwater BMPs should prevent an estimated 80% of the stormwater TSS load from reaching Hangman Creek.
- WWTPs are insignificant sources of turbidity and solids in Hangman Creek compared to event-based erosion. Current municipal NPDES permits limit TSS to loads far lower than are of concern in the watershed, and permit limits will be adequate as wasteload allocations.

- WARMF or a similar model should be supported with better local data for calibration and scenario-building.

Allocation for future growth

Municipal stormwater effects from additional residential growth are included in the modeling scenarios by increasing residential land use in the lower Hangman watershed. The lower watershed is not among the 303(d) listed areas. A growth allocation is not set aside, but a 10% increase is TSS from residential and commercial areas in the lower watershed is predicted. Spokane County, City of Spokane, and WSDOT are required to limit pollutant discharge in stormwater using BMPs. Actions preventing the additional loading to Hangman Creek are recommended.

Growth in this case is the conversion of agriculture, forest, and range lands to residential uses. The small municipalities and communities in the watershed are not expected to experience significant growth in the 5-10 year time-scale of this TMDL evaluation. Agricultural expansion or intensity is difficult to predict. The variability in cultivation intensity from 1998 to 2005 was used to set load capacities for the watershed and should be protective of future variability.

Margin of safety

The federal Clean Water Act requires that TMDLs be established with margins of safety (MOS). The MOS accounts for uncertainty in the available data, or the unknown effectiveness of the water quality controls that are put in place. The MOS can be stated explicitly (e.g., a portion of the load capacity is set aside specifically for the MOS). But, implicit expressions of the MOS are also allowed such as conservative assumptions in the use of data, application of models, and the effectiveness of proposed management practices.

Implicit margin of safety factors were included in the development of the suspended sediment TMDL:

- The models consider long-term transport of suspended sediment from the entire Hangman Creek watershed without regard to distance or political borders.
- The allocations include periods of time (1998 – 2000) before improvements were made in the watershed to reduce upland and streambank erosion.
- Conservative erosion, land use, and initial condition terms were used in the WARMF model.

Monitoring Recommendations

As a result of this TMDL study, the following monitoring recommendations are made:

- Specific sources of fecal coliform contamination should be identified in reaches of interest.

- Stormwater monitoring should include fecal coliform, temperature, and turbidity and total suspended solids (TSS) to better characterize pollutant loads coming from this source. If necessary, wasteload and load allocations may need to be adjusted based on an improved understanding of stormwater pollutant loads.

- All of the WWTPs should monitor receiving water and effluent temperatures and discharge volumes during the spring through fall season. When the thermal and dilution cycles are better understood, compliance schedules and operational/facility options can be better designed.

- Fish and aquatic communities should be evaluated in mainstem and tributary reaches of interest.

- Future WARMF model development for TSS will require additional data or analysis:
  - Precipitation data from several areas within the watershed.
  - Continuous streamflow and routine TSS monitoring at major tributaries and points along the mainstem.
  - Erosion rates from streambank and upland areas of the watershed.
  - The number of systems and rates of on-site septic failure in various sub-watersheds.
  - Repair of the riparian buffer zone function of the model.

- Dissolved oxygen and pH 303(d) listings were not evaluated as part of this study and will need to be characterized in the future.

- Reference sites will need to be established for distinct reaches of interest before turbidity criteria are applied.

- To evaluate compliance with the TSS TMDL, sediment rating curves (Figure 41) should be developed for Rock Creek, Rattler Run, Hangman Creek at State Line (Road), Little Hangman Creek, and Hangman Creek at Bradshaw.

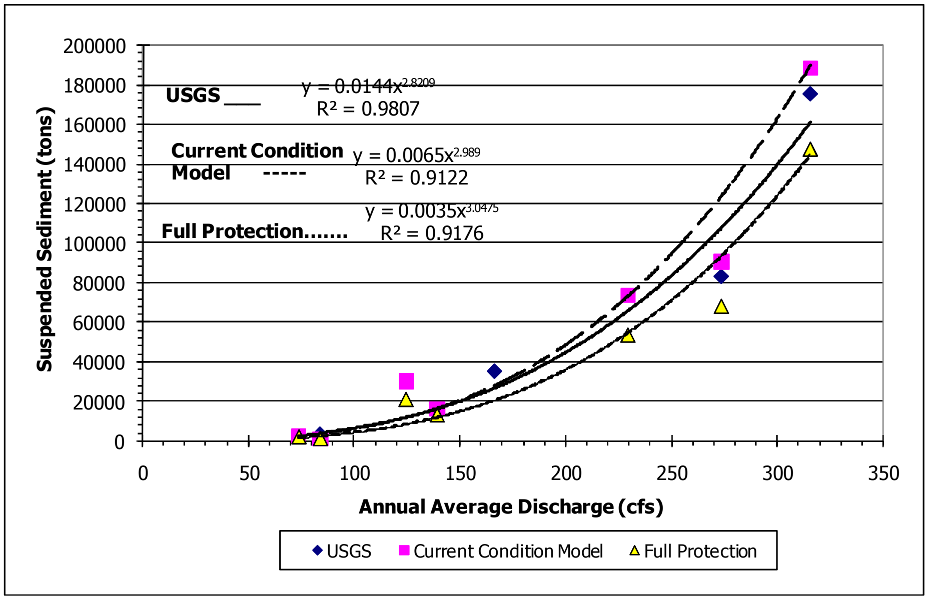


Figure 41. A sediment rating curve for the mouth of Hangman Creek comparing the estimated full protection scenario curve to the current model and USGS data curves.

Implementation Strategy

Introduction

This *Implementation Strategy* describes what will be done to improve water quality. It describes the roles and authorities of cleanup partners (that is, those organizations with jurisdiction, authority, or direct responsibility for cleanup) and the programs or other means through which they will address these water quality issues. It provides a feasible and effective strategy to achieve the water quality standards for fecal coliform bacteria, turbidity, and temperature. Because of regional interest in reducing Hangman Creek's phosphorus contribution to the Spokane River, this *Implementation Strategy* also includes strategies to reduce nutrients. The development of this plan was a collaborative effort by a diverse group of interests in the watershed and was facilitated by the Spokane County Conservation District (SCCD).

After the U.S. Environmental Protection Agency (EPA) approves this TMDL, interested and responsible parties will work together to develop a *Water Quality Implementation Plan*. The plan will describe and prioritize specific actions planned to improve water quality and achieve water quality standards.

What needs to be done?

The Hangman Creek Advisory Committee first met in April 2004. The committee formed at the April 2004 meeting and has been meeting approximately monthly. The intent of the committee was to identify water quality issues in the watershed that are related to increased loads of fecal coliform, phosphorus, total suspended solids (turbidity), and heat (temperature). The committee then developed a list of Best Management Practices (BMPs) that may offer one or more solutions for each issue. This report reflects the local stakeholders' awareness of the water quality problems and related issues. This report was developed locally to reflect the local needs, values, and priorities.

The water-quality-related issues evaluated for the TMDLs and phosphorus by the committee were:

- Issue 1: Sediment/nutrients from agricultural operations
- Issue 2: Sediment/fecal coliform from livestock and wildlife
- Issue 3: Nutrients/chemicals from residential uses
- Issue 4: Sediment/nutrients from agricultural field ditches
- Issue 5: Nutrients/fecal coliform from improper functioning septic systems
- Issue 6: Sediment from gravel and summer roads
- Issue 7: Sediment from sheer or undercut banks
- Issue 8: Sediment/fecal coliform from stormwater
- Issue 9: Sediment from poor forestry management
- Issue 10: Sediment from roadside ditching
- Issue 11: Solar heating from lack of riparian shade

Other water quality issues were identified for the Hangman watershed during the public meetings and by the committee. The following issues were reviewed by the committee, but because they were not actual issues directly affecting the parameters of interest (fecal coliform, turbidity/TSS, temperature, and phosphorus), or they were outside the scope of what this effort could reasonably achieve, they were not included as issues to address through implementation activities for the TMDL.

- Sediment from sandbanks in the lower part of the watershed
- Chemicals from road deicer
- Chemicals from agricultural chemical application
- County enforcement of regulations
- State enforcement of regulations
- Development/Permits
- New wetland construction and maintenance of existing wetlands
- Maintain/increase existing healthy, functioning riparian areas
- Return stream to original channel
- Drain tile in agricultural fields
- Rock pits/blasting
- Increase instream flows
- Invasive aquatic plants
- Beaver ponds

The 11 issues identified by the Advisory Committee need to be addressed to bring the streams in the Hangman Creek Watershed into compliance with the water quality standards and reduce the phosphorus entering the Spokane River. The technical analysis earlier in this document helps prioritize where initial efforts should be focused by setting wasteload and load allocations for three parameters: 1) fecal coliform bacteria, 2) temperature, and 3) turbidity/total suspended solids (TSS). Wasteload allocations were established for the six wastewater treatment facilities and the three entities covered under a stormwater permit. The wasteload allocations will ensure these facilities discharge pollutants at a level that is protective of water quality.

The load allocations to address nonpoint sources of the pollutants are set geographically by establishing the reductions needed at different points throughout the watershed and sub-watersheds. Most nonpoint sources are present throughout the watershed, although urban sources are more concentrated in the lower part of the watershed.

Possible point and nonpoint sources for each parameter in this TMDL are indicated in Table 31.

Table 31. Possible Sources of Each Pollutant.

Possible Source	Fecal Coliform Bacteria	Temperature	Total Phosphorus	Turbidity/ Total Suspended Solids
Agricultural operations		x	x	x
Livestock	x	x	x	x
Wildlife	x		x	
Residential fertilizer use			x	
Agricultural field ditches			x	x
Malfunctioning septic systems	x		x	
Gravel and summer roads			x	x
Sheer and undercut streambanks			x	x
Stormwater	x		x	x
Roadside ditching			x	x
Wastewater treatment plants	x	x	x	x
Forestry management		x		x

The point sources (wastewater treatment plants and stormwater facilities) will be addressed through the issuance of their NPDES permits. These permits will reflect the wasteload allocations established earlier in this document and if necessary a compliance schedule to meet those allocations. More detail about the implementation of these wasteload allocations is discussed below under "Who Needs to Participate."

To address the nonpoint sources, the advisory committee developed a list of BMPs to address each of the nonpoint source water quality issues identified. Stormwater is included because much of the watershed is not covered under a stormwater permit. Stormwater BMPs may also be necessary in these rural areas to reduce pollutant loading. The advisory committee worked through each BMP identifying potential barriers and benefits to implementing each one (Appendix D). The purpose of this exercise was to lay the groundwork for the implementation plan. An understanding of the barriers agencies and organizations may encounter when trying to improve water quality should facilitate implementation. Likewise, understanding the benefits of the BMPs will help education and outreach efforts during implementation. Appendix D outlines the results of this exercise.

Many of the BMPs address more than one of the water quality issues. To address the water quality parameters addressed by this TMDL, pollution reductions will be accomplished through BMPs that:

- Reduce erosion.
- Reduce runoff carrying sediment.
- Reduce livestock impacts.
- Increase shading of streams.
- Inform and educate watershed residents about water quality issues.

Since the wasteload allocations are implemented through a NPDES permit, the Implementation Plan drafted following the completion and approval of this TMDL will focus on steps to reduce nonpoint source pollution. The Implementation Plan will build on the BMPs listed in Table 32. This table shows the BMPs the advisory committee believed would help address each water quality issue identified. The implementation plan will specify how various entities will implement actions to increase or initiate these BMPs throughout the watershed. While these BMPs are a starting point for implementation planning, other BMPs and activities will also be included in the Implementation Plan. Ecology and the SCCD will meet with entities to get their commitments to activities to reduce nonpoint source pollution in the watershed.

Water Quality Issue	Best Management Practices						
Issue 1: Sediment/nutrients from agricultural operations	Direct Seed Tillage Operations (No Till/Minimum Till)	Riparian Buffers	Sediment Basins	Grassed Waterways	Filter Strips	Divided Slopes	Reforestation
Issue 2: Sediment/fecal coliform from livestock and wildlife	Riparian Buffers	Livestock Fencing and off-stream watering	Manure Retention Facilities	Off-Stream Watering	Intensive Management Grazing	Nutrient and manure management	
Issue 3: Nutrients/chemicals from residential uses	Education about fertilizer management	Septic system maintenance, repair and replacement	Pet waste management	Proper use and disposal of household chemicals	Proper use and disposal of pesticides and fertilzers	Proper disposal of lawn clippings	Follow shoreline management regulations
Issue 4: Sediment/nutrients from agricultural field ditches	Uphill plowing	Ditch maintenance	Proper construction and engineering	Conversion to grassed waterways			
Issue 5: Nutrients/fecal coliform from improper functioning septic systems	Education on the negative affects of garbage disposals	Have system inspected every 1-3 years	Remove roof drains from system and away from the drainfield	Education about what should and should not go into septic systems	Comment on new developments through SEPA process	Repair or replace failing systems	
Issue 6: Sediment from gravel and summer roads	Pave roads	Close roads in winter	Increase grading and graveling				
Issue 7: Sediment from sheer or undercut banks	Plant vegetation	Reshape banks and plant vegetation	Install engineered structures				
Issue 8: Sediment/fecal coliform from stormwater	Road runoff to sediment basins	Implement practices in the Eastern Washington Stormwater Manual					
Issue 9: Sediment from poor forestry management	Selective harvest	Stream crossings need to follow requirements in WAC 222-24-040	Forested streamside management zones required for fish-bearing and perennial non-fish waters (WAC 222-30)	Limit equipment in streamside management zones for seasonal non-fish waters (WAC 222-30)	Proper road planning, construction and maintenance (follow WAC 222-24)		
Issue 10: Sediment from roadside ditching	Design and implement vegetated ditches	Install detention basins					
Issue 11: Solar heating from lack of riparian shade	Riparian restoration projects	Riparian buffers	Livestock fencing and off-stream watering				

Table 32. Best Management Practices (BMPs) for water quality issues related to sources of pollutants covered by this TMDL.

Who needs to participate?

Implementation activities will generally involve the agencies responsible for the development of the *Implementation Strategy*; namely, the Spokane County Conservation District, Washington Department of Ecology, Spokane County, the City of Spokane, the 6 wastewater treatment plants, the Coeur d'Alene Tribe and the Environmental Protection Agency. Implementation will be jointly facilitated and tracked by the Spokane County Conservation District and the Department of Ecology. These agencies will also involve other agencies and groups, such as the Spokane Regional Health District, the Direct Seed Association, Washington State University Extension, seed and fertilizer companies, local producer based cooperatives, the Natural Resources Conservation Service, and the Farm Service Agency. To effectively reduce nonpoint source pollution, these agencies will need to seek cooperation with private landowners to implement BMPs designed to address the pollution issues.

Washington Department of Ecology

Ecology will work with the various agencies in the watershed to ensure progress is being made toward meeting the water quality standards for fecal coliform, temperature and TSS/turbidity and toward meeting the proposed phosphorus allocations set by the draft *Spokane River Dissolved Oxygen TMDL*. Ecology, in cooperation with the SCCD will develop a Water Quality Implementation Plan (WQIP) which will detail the specific activities that will be done to facilitate meeting these goals.

Ecology will regulate stormwater discharges through the Construction, Municipal, Industrial, and the WSDOT Stormwater Permits.

A ***Construction Stormwater Permit*** is required for all soil disturbing activities (including clearing, grading, and/or excavation) where one or more acre will be disturbed, and stormwater will be directly discharged to a receiving water (e.g., wetlands, creeks, unnamed creeks, rivers, marine waters, ditches, estuaries), or to storm drains that discharge to a receiving water. A permit is also required for construction projects smaller than one acre if the project is part of a "common plan of development or sale" in which the total land disturbance exceeds one acre. Any size construction activity may be required to obtain a permit if Ecology determines it to be a significant source of pollutants to waters of the state. If all stormwater is retained on-site and cannot enter surface waters of the state under any condition, permit coverage is not needed. Construction site operators must apply for a permit 60 days prior to discharging stormwater.

A ***Municipal Stormwater Permit*** is required for public entities in urbanized areas (as defined by the 2000 Census) that operate municipal separate storm sewer systems (MS4). The City of Spokane and a portion Spokane County are included under the Phase II Municipal Stormwater Permit for Eastern Washington. Only portions of Spokane County within the census defined urbanized area are covered by the permit (Figure 42).

Coverage under the ***Industrial Stormwater General Permit*** is required for industrial facilities that discharge stormwater from their industrial areas to waters of the state, or to storm drains that discharge to waters of the state. No permit is required if the facility treats and retains all the stormwater on site. Coverage may be required of facilities that are significant contributors of pollutants to groundwater even though no discharge to surface water or storm sewer exists.

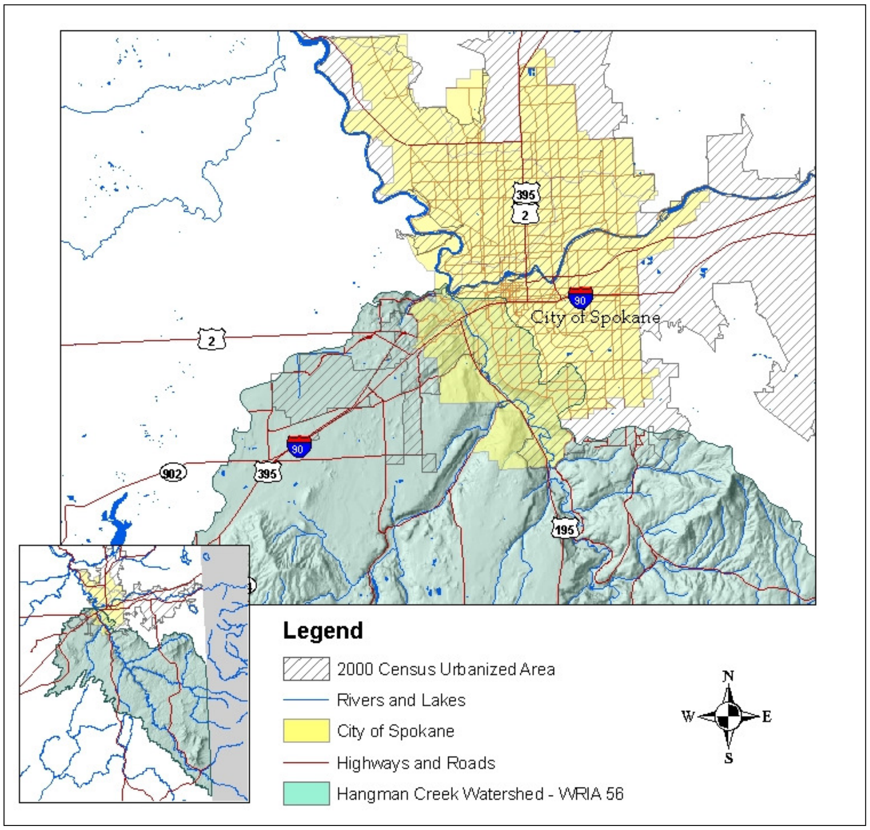


Figure 42. Urbanized areas shows portion of Hangman Creek Watershed covered by Phase II NPDES Stormwater Permit.

The WSDOT stormwater NPDES permit requires WSDOT to implement its stormwater management program (SWMP), which includes water quality monitoring and field investigations of illicit discharges into its conveyances. WSDOT shall report the findings of its investigations and the actions taken to implement its SWMP to Ecology in the annual report.

Ecology will include WLAs for all addressed parameters in the NPDES permits for Tekoa, Fairfield, Spangle, Rockford, Cheney, and the Freeman School District's WWTPs. These WLAs will ensure point sources are not causing the streams to violate water quality standards. The NPDES permits will include monitoring requirements and if necessary future permits will include a compliance schedule. Ecology recognizes the difficultly of meeting the temperature

WLAs even with treatment plant improvements and will continue to work with the facilities to find solutions. Considering the temperature analysis indicates the streams could not meet the numeric criteria even under the system-potential vegetation conditions, Ecology will consider evidence indicating whether or not the correct water quality criteria are being applied. Such evidence may include evaluations of current and potential beneficial uses.

Ecology's Water Quality Program will also monitor the progress of the WQIP, review monitoring data, and apply adaptive management if implementation does not move the streams towards meeting water quality goals in a timely enough manner.

Spokane County Conservation District

The Spokane County Conservation District (SCCD), in cooperation with Ecology will develop a Water Quality Implementation Plan (WQIP) which will outline the specific activities that will be done to meet the goals of this TMDL. The SCCD will use existing and future funding sources to implement BMPs, activities and educational programs recommended in this report and the future WQIP. The SCCD will provide technical assistance to landowners who want to restore riparian areas, fence livestock from streams, implement direct seed tillage operations and other conservation activities.

Tekoa, Fairfield, Rockford, Spangle, Cheney and the Freeman School District's Wastewater Treatment Plants

The current limits for turbidity and solids in the NPDES permits for these facilities are adequate to protect water quality and will be continued as wasteload allocations (WLAs) in future permits. All current permit limits for fecal coliform, except Tekoa are adequate to protect water quality. The Tekoa permit limits will be reduced to match the limits of the other permits to assure they are protective of water quality. The recommended temperature wasteload allocations will be incorporated into their NPDES permits when they are re-issued. Improvements to each of the facilities may be necessary to meet the WLAs for temperature. The temperature WLAs may be difficult for these facilities to meet considering technological and financial limitations. The NPDES permits should contain compliance schedules that outline a reasonable schedule for meeting these targets.

Some options these facilities can consider to reduce their effluent temperature are discussed in "Methods to Reduce or Avoid Thermal Impacts to Surface Water" (Skillings Connolly, Inc, 2007). Samples of these options include:

- Clarifier covers.
- Seasonal storage.
- Land application.
- Infiltration trenches.
- Wastewater reclamation and reuse.
- Riparian shading.

Interim temperature effluent limits and compliance schedules will be developed using Ecology's "Water Quality Program Guidance – Implementing Washington State Temperature Standards through TMDLs and NPDES Permits" (Hicks, 2007). Facilities not assigned a wasteload allocation are not expected to discharge during the critical period (June-August). If it becomes necessary to discharge during this period, Ecology will require them to meet wasteload allocations assigned to Tekoa until site specific wasteload allocations can be developed. All six facilities will be required to monitor temperature as part of their permit monitoring requirements.

All facilities should include steps to reduce nutrients in their effluent. Future efforts to meet the *Spokane River and Lake Spokane Dissolved Oxygen TMDL* and to address dissolved oxygen and pH listings in the Hangman Creek watershed will likely result in very restrictive nutrient wasteload allocations. These considerations should be included in any treatment plant upgrades or changes.

All facilities will need to initiate monitoring phosphorus concentrations and loads in their effluent. This data may be used in future efforts to control phosphorus or to development TMDLs for dissolved oxygen and pH.

City of Spokane, Spokane County and WSDOT

The activities recommended in this TMDL include controlling sediment (TSS/turbidity), and fecal coliform from stormwater. Spokane County and the City of Spokane have been included under the Phase II Municipal Stormwater Permit. In addition, WSDOT highways within these Phase II areas are included under WSDOT's stormwater permit. These permits require the implementation of the following stormwater management elements:

- Public education and outreach
- Public involvement and participation
- Illicit discharge detection and elimination
- Construction site stormwater runoff control
- Post-construction stormwater management
- Pollution prevention and good housekeeping for municipal operations
- Requirements based on approved Total Maximum Daily Loads (TMDLs)
- Evaluations of program compliance

Many pollutants in stormwater can be controlled through BMPs. The Eastern Washington Stormwater Manual recommends various BMPs to address specific pollutants.

The stormwater permits for these entities will be re-issued in 2012. As a result of this TMDL, the following activities may be included in the revised permit:

- Inventory stormwater outfalls to determine which outfalls have the greatest impacts directly to waterbodies.
- Include fecal coliform, turbidity and total suspended solids in stormwater monitoring to better characterize pollutant loads coming from this source. If necessary, wasteload and load allocations may be adjusted based on an improved understanding of stormwater pollutant loads. It is unlikely that stormwater temperature will impact in-stream water temperature.

However, if the City, County or WSDOT have large impervious areas that could hold stormwater allowing it to heat before discharging to a stream, temperature must be monitored in these areas.

- All stormwater monitoring requires an approved Quality Assurance Project Plan.
- Capture storm events in the monitoring effort.
- Monitoring results will be compared to the WLAs established in this TMDL and if the results exceed the allocations, appropriate BMPs will be put into place to protect water quality.
- Education programs will need to target developers, businesses, and residents in the lower Hangman Creek and Marshall Creek area to prevent pollution to stormwater systems.

To implement the regulations, Ecology uses a narrative Best Management Practice (BMP) approach to stormwater control rather than numeric effluent limitations. The Permit and the stormwater manual approach defines the level of effort required for each of the requirements as part of the permit development and issuance process. It bases requirements on recognized practices from existing programs, uses compliance schedules where appropriate, focuses efforts on development of local programs that protect existing water quality rather than restoring degraded areas (except where mandated by TMDLs), and requires each permit holder to evaluate the effectiveness of the entity's Stormwater Management Program (SWMP). Once the NPDES municipal permit activities are fully implemented and the effectiveness has been evaluated, Ecology may need to consider additional activities to address pollutants from stormwater sources.

Department of Natural Resources and Forest Practitioners

The state's forest practices regulations will be relied upon to bring waters into compliance with the load allocations established in this TMDL on private and state forestlands. As part of the 1999 Forests and Fish agreement (www.dnr.wa.gov/forestpractices/rules/forestsandfish.pdf), Ecology agreed to use the forest practices regulations to implement TMDLs. The effectiveness of the Forests and Fish program is being assessed through a formal adaptive management program. The success of this TMDL will be assessed using monitoring data from streams in the watershed.

Ecology will formally review the effectiveness of the forest practices program in 2009. As part of this review, Ecology will determine if the state's forest practices program can be relied on to bring water quality into compliance with the state water quality standards. If the current program is not found to be adequate, Ecology will suggest any needed changes to the Forest Practices Board, or revise this TMDL implementation plan as necessary, to achieve compliance.

Washington State Department of Natural Resources (DNR) is encouraged to condition forest practices to prohibit any further reduction of stream shade and not waive or modify any shade requirements for timber harvesting activities on state and private lands.

New forest practices rules for roads also apply. These include new road construction standards, as well as new standards and a schedule for upgrading existing roads. Under the new rules, roads must provide for better control of road-related sediments, provide better streambank stability protection, and meet current BMPs. DNR is also responsible for oversight of these activities.

Private Landowners and Watershed Residents

The Hangman Creek watershed's water quality problems are primarily from nonpoint sources of pollution. Nonpoint source pollution results from the actions of all people living in a watershed; therefore everyday activities by citizens can have a significant impact on local water quality. Actions watershed residents can take to lessen their impact include properly disposing of and managing animal waste, avoiding placing grass clippings in or near streambanks, restoring their riparian areas, implementing farming practices that reduce erosion, repairing failing or regularly pumping septic systems and educating others about the impacts of their everyday actions on water quality. Many of the agencies and organization mentioned in this plan can provide technical or financial assistance to landowners and residents for these activities.

Coeur d'Alene Tribe and the Environmental Protection Agency (EPA)

The Coeur d'Alene tribe (CDA) has their own water quality standards and has been collecting data for developing TMDLs for waterbodies not meeting these standards. Their water quality standards are similar to Washington's water quality standards but have not been approved by the EPA. Hangman Creek is impaired for bacteria, habitat alteration, nutrients and sediment from the Reservation boundary to the Idaho/Washington state line. Little Hangman Creek, a tributary to Hangman Creek, is impaired from its headwaters to the state line for nutrients.

The Tribe has actively participated in the development of Washington's TMDL by providing data and local knowledge. Ecology modeled the whole watershed based on the data provided by the Tribe. The technical analyses in this TMDL include targets set at the border which ensure compliance with Washington's water quality standards. The CDA Tribe in cooperation with EPA will develop TMDLs for the reservation waterways based on meeting their own water quality standards and the targets set at the border.

The EPA will need to ensure the Tensed, DesMet and Worley treatment plants and any new wastewater facilities that discharge to surface water have NPDES permits protective of Washington's water quality standards and this TMDL.

What is the schedule for achieving water quality standards?

The ability to meet specific interim targets and milestones will depend on the funds available, the personnel and resources available, and the producers in the watershed. Some pollutants will take longer to reach water quality standards than others. For example, it will take longer to reach the temperature standards because of the time it takes to grow plants and trees that will shade the streams. TSS will require the establishment of functioning riparian areas, streambank stabilization and other measures throughout the watershed. A proposed schedule for achieving water quality standards for each pollutant is shown in Table 33.

Table 33. Schedules for achieving water quality standards.

Percentage of TMDL targets achieved	Number of Years after TMDL Water Quality Improvement Plan completion		
	Fecal Coliform	Temperature	Turbidity/TSS
25%	3	10	5
50%	5	15	7
75%	8	20	10
100%	10	25	15

These targets will require significant commitment from all stakeholders. Without watershed wide commitment the targets may not be met. If the Idaho portion of the watershed does not commit to the goals of this TMDL, progress on the Washington side could be delayed.

Reasonable assurances

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint sources) in the waterbody. In the Hangman Creek watershed both point and nonpoint sources exist for fecal coliform, temperature, turbidity and total suspended solids. TMDLs (and related Action Plans) must show "reasonable assurance" that these sources will be reduced to their allocated amount. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this water improvement plan are met.

There is considerable interest and local involvement toward resolving the water quality problems in the Hangman Creek watershed. Numerous organizations and agencies are already engaged in stream restoration and source correction actions that will help resolve the fecal coliform, temperature, sediment/turbidity, and phosphorus problems.

Ecology and the SCCD believe that the following activities are already supporting this TMDL and add to the assurance that fecal coliform, temperature, and turbidity/total suspended solids in Hangman Creek will meet conditions required by Washington State water quality standards. This assumes that the activities described below are continued and maintained.

Ongoing-Efforts

Several local agencies have ongoing efforts that increase awareness of water quality issues in the watershed. Ecology, the conservation districts, Washington State University Extension, Spokane and Whitman counties, and the county Health Departments all have pamphlets, mailers, workshops and outreach programs on water quality education. Technical assistance is provided by NRCS, the Conservation Districts, and the Department of Ecology. The following are some of the current programs in the Hangman Creek watershed that provided some type of nonpoint pollution control or environmental education.

Hangman Creek Watershed Planning (WRIA 56)

The 1998 legislature passed ESHB 2514, codified into Ch. 90.82 RCW, to set a framework for developing local solutions to watershed issues on a watershed basis. Watershed Planning Units must plan for future water quantity needs but they can also choose to plan for water quality needs. The Hangman Creek Watershed Planning Unit formed in 1999 and opted to include water quality issues in their watershed plan. The Planning Unit completed their watershed plan in 2006 which includes many recommendations to improve water quality including participation in activities recommended in the TMDL. In February 2008, the planning unit completed a Detailed Implementation Plan which outlines how and when various activities will be completed. This project has an education component, recommendations for increasing stream flows, and several recommendations for improved water quality.

Spokane River and Lake Spokane Dissolved Oxygen TMDL

The draft *Spokane River and Lake Spokane Dissolved Oxygen TMDL* relies partially on the reduction of phosphorus coming from Hangman Creek. Therefore, Spokane River dischargers have interest in implementing BMPs in the Hangman Creek to help offset portions of their TP phosphorus allocations. BMPs that reduce phosphorus will likely also reduce fecal coliform, temperature and turbidity/TSS. Ecology and SCCD anticipate that many cooperative partnerships will be formed between entities involved in both TMDLs.

Spokane County Volunteer Water Quality Monitoring Project

The program is currently using volunteers to monitor water quality in the Hangman watershed at select locations. This program was started with an Ecology grant, but is currently being funded by the SCCD.

Spokane County Shorelines Inventory and Assessment Project (Ecology Grant)

This project by the SCCD evaluated and inventoried the riparian areas along Hangman, Rock, and California creeks. This provided a ranking system to target funding and technical assistance to areas of high priority for water quality restoration. This information will help prioritize future implementation activities.

Regulatory and Technical Assistance Programs

The following describes existing regulatory and technical assistance programs that provide reasonable assurance that the goals of this TMDL will be met.

Washington Department of Ecology

Ecology has authority under the federal Clean Water Act by EPA to establish water quality standards, administer the NPDES wastewater permitting program, and enforce water quality regulations under Chapter 90.48 RCW. Ecology responds to complaints, conducts inspections, and issues NPDES permits as part of its responsibilities under state and federal laws and regulations. In cooperation with conservation districts, Ecology will pursue implementation of BMPs for agricultural and other land uses and may use formal enforcement, including fines, if voluntary compliance is unsuccessful.

Spokane County Conservation District and Pine Conservation District

The conservation districts have authority under Chapter 89.08 RCW to develop farm plans, protect water quality, and to provide animal waste management information, education and technical assistance to residents on a voluntary basis. Farmers receiving a Notice of Correction from Ecology or local health jurisdictions will normally be referred to the local conservation district for assistance. When developing farm plans, the districts use guidance and specifications from the U.S. Natural Resources Conservation Service.

In addition, the conservation districts seek and receive grant funds that will assist landowners to implement BMPs that improve riparian health and protect water quality to Hangman Creek and its associated tributaries.

Natural Resources Conservation Service (NRCS)

NRCS works closely with conservation districts to implement farm plans and agricultural BMP programs. NRCS is one of the primary entities for technical assistance and financial support to assist in the implementation of agricultural and livestock BMPs throughout the watershed.

Spokane and Whitman County Health Departments

The health departments regulate on-site sewage systems in the watershed in accordance with Chapter 246-272 WAC. When the department receives a complaint about a failing system, the department verifies the failure and assists the landowner with coming into compliance with Chapter 246-272 WAC. In addition, the health departments are often involved in the investigation of complaints about agricultural animal waste.

Spokane County, Whitman County, and City of Spokane

Hangman Creek falls under the requirements of the Shoreline Management Act (SMA) (RCW 90.58). The SMA is administered principally by local governments through locally developed Shoreline Master Programs (SMPs) and Ecology provides technical and financial assistance for the development and implementation of the SMPs.

Ecology reviews and approves the SMPs, and with local governments, has the authority for compliance and enforcement of the SMA and SMPs. Local governments review projects in their jurisdiction for compliance with local SMPs and the SMA, through a permit process. The SMA specifically lists protecting water quality as a purpose of the SMA (RCW 90.58.020). Local governments must periodically update their SMPs and must integrate them with their Growth Management Act provisions, including critical area ordinances. Spokane County began updating their SMP in 2003 and anticipates its completion in 2008.

State of Idaho, Coeur d'Alene Tribe, Environmental Protection Agency (EPA)

Since Hangman Creek, Little Hangman Creek and Rock Creek originate in Idaho, the work underway in Idaho and on the Coeur d'Alene Reservation has the potential to positively affect water quality in the Washington portion of the watershed. In Idaho, the water quality standards program is a joint effort between the Department of Environmental Quality (DEQ) and the EPA. DEQ is responsible for developing and enforcing water quality standards that protect beneficial uses such as drinking water, coldwater fisheries, industrial water supply, recreation, and agricultural water supply. Likewise, the Coeur d'Alene Tribe has its own water quality standards and programs for the protection of surface water. The DEQ and Tribe have the authority and the responsibility to ensure that TMDLs are completed and submitted to EPA. The EPA develops regulations, policies, and guidance to help DEQ and the Tribe implement their programs and to ensure that their water quality standards and TMDLs are consistent with the requirements of the Clean Water Act and relevant regulations. The EPA has authority to review and approve (or disapprove) state standards and, where necessary, to promulgate federal water quality rules.

IDEQ completed a TMDL for the Upper Hangman Creek watershed for temperature, sediment and *E. coli* which was approved by EPA in 2007. The TMDL addresses streams outside the Coeur d'Alene Indian Reservation and encompasses approximately 10,000 acres. This TMDL establishes load allocations and reductions that, once met, are anticipated to restore beneficial uses and meet Idaho water quality standards. This TMDL should result in cleaner water entering Washington's portion of the watershed.

Data is also being collected to develop TMDLs for the portion of streams on the Coeur d'Alene Tribal Reservation. The Coeur d'Alene Tribe participated in the development of the Washington TMDLs and concurs with the base assumptions used to create these TMDLs (personal communication with Scott Fields, email 1/16/09).

Adaptive management

TMDL reductions for all parameters should be observable within 15 years of TMDL adoption. How quickly water quality standards will be achieved will depend on the specific parameter, the causes of the impairment and the availability of funding sources. The *Water Quality Implementation Plan* will identify interim targets. These targets will be described in terms of concentrations and/or loads, as well as in terms of implemented cleanup actions. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the cleanup strategy as needed.

It is ultimately Ecology's responsibility to assure that cleanup is being actively pursued and water quality standards are achieved. See the *Monitoring Progress* section in this report. Adaptive management methods that may be used during implementation of this TMDL include:

- Adjusting BMPs.
- Modifying stream sampling frequency and/or locations.
- Developing and funding water quality projects that address pollution loads.
- Local educational initiatives.
- Assessing local watershed needs.

The load and wasteload allocations in this TMDL may be adjusted as more data and information about the transport of pollutants through the watershed is gathered.

Monitoring progress

A TMDL must include monitoring to measure achievement of targets and water quality standards. Monitoring also provides evidence that BMPs are having the desired results.

A quality assurance project plan (QAPP) should be prepared for all monitoring conducted. The QAPP should follow Ecology guidelines (Lombard and Kirchmer, 2004) paying particular attention to consistency in sampling and analytical methods.

The purpose of effectiveness monitoring is to discover if management activities and BMPs are improving water quality. Effectiveness monitoring results are used to determine if the interim targets and/or water quality standards are being achieved. Ecology usually performs this monitoring five years after the Water Quality Implementation Plan is finished. The ability for Ecology to conduct the monitoring in five years depends upon the availability of resources. If the streams are found to not meet the interim targets and/or water quality criteria, an adaptive management strategy will be adopted and future effectiveness monitoring will need to be scheduled.

The NPDES permits issued for the point sources in the watershed will require regular monitoring of fecal coliform, temperature, turbidity/total suspended solids and phosphorus levels in the treatment plant’s effluent to ensure the facilities are in compliance with the permit limits or compliance schedule.

As BMP projects are put into place, monitoring on a project specific basis will be done as required by the granting or funding agency. Monitoring for watershed improvements will be scheduled at five-year intervals, depending on funding availability. The monitoring plan will be changed if necessary as an element of adaptive management.

To determine the effectiveness of the TSS reduction efforts, fish population and habitat condition assessments may be necessary. Scientists at Eastern Washington University, Washington State Department of Fish and Wildlife and the Coeur d’Alene Tribal biologists may be able to help determine the success of this portion of the TMDL.

Entities with enforcement authority are responsible for following up on any enforcement actions. Stormwater permittees are responsible for meeting the monitoring requirements of their permits. Organizations conducting restoration projects or installing BMPs are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

During the next phase of this TMDL effort Ecology and the SCCD will develop a The *Water Quality Implementation Plan* (WQIP) which will outline a monitoring strategy which includes the monitoring recommendations made in the TMDL Analyses section of this report. Ecology and the SCCD will monitor the progress made towards implementing the actions outlined in this TMDL and the WQIP.

Potential funding sources

Ecology's Centennial Clean Water Fund, Section 319, and State Revolving Fund loans can provide funding resources to help implementation of the TMDL (water quality improvement plan). In addition to Ecology's funding programs, there are many other funding sources available for watershed planning and implementation, point and nonpoint source pollution management, fish and wildlife habitat enhancement, stream restoration, and education. Public sources of funding include federal and state government programs, which can offer financial as well as technical assistance. Private sources of funding include private foundations, which most often fund nonprofit organizations with tax-exempt status. Forming partnerships with other government agencies, nonprofit organizations, and private businesses can often be the most effective approach to maximize funding opportunities. Some of the most commonly accessed funding sources for TMDL implementation efforts are shown in Table 34 and are described below.

Table 34. Potential Funding Sources for Implementation Projects.

Fund Source	Type of Project Funded	Maximum Amounts
Centennial Clean Water Fund	Watershed planning, stream restoration, & water pollution control projects.	$500,000
Section 319 Nonpoint Source Fund	Nonpoint source control; i.e., pet waste, stormwater runoff, & agriculture, etc.	$500,000
State Water Pollution Control Revolving Fund	Low-interest loans to upgrade pollution control facilities to address nonpoint source problems; failing septic systems.	10% of total SRF annually
Coastal Zone Protection Fund (also referred to as Terry Husseman grants)	Stream restoration projects to improve water quality.	~$50,000
Conservation Reserve Program (CRP)	Establishes long-term conservation cover of grasses, trees and shrubs on eligible land.	Rental payments based on the value of the land; plus 50% - 90% cost share dependant on practices implemented
Environmental Quality Incentives Program (EQIP)	Natural resource protection.	Dependent on practices implemented
Wildlife Habitat Incentive Program (WHIP)	Provide funds to enhance and protect wildlife habitat including water.	$25,000 dependent on practices implemented
Conservation Security Program (CSP)	Provides financial assistance for conservation on private working lands	Dependent on practices implemented
Housing Rehabilitation Loan Program	Loans to low-income homeowners for safety & sanitation.	0-6% interest dependent on household income
Wetland Reserve Program (WRP)	Wetland enhancement, restoration, and protection by retiring agricultural land.	Dependent on appraised land value

Centennial Clean Water Fund (CCWF)

A 1986 state statute created the Water Quality Account, which includes the Centennial Clean Water Fund (CCWF). Ecology offers CCWF grants and loans to local governments, tribes, and other public entities for water pollution control projects. The application process is the same for CCWF, 319 Nonpoint Source Fund, and the state Water Pollution Control Revolving Fund.

Section 319 Nonpoint Source Fund

The 319 Fund provides grants to local governments, tribes, state agencies and nonprofit organizations to address nonpoint source pollution to improve and protect water quality. Nonpoint source pollution includes many diffuse sources of pollution, such as stormwater runoff from urban development, agricultural and timber practices, failing septic systems, pet waste, gardening, and other activities. Non-governmental organizations can apply to Ecology for funding through a 319 grant to provide additional implementation assistance.

State Water Pollution Control Revolving Fund

Ecology also administers the Washington State Water Pollution Control Revolving Fund. This program uses federal funding from U.S. Environmental Protection Agency and monies appropriated from the state's Water Quality Account to provide low-interest loans to local governments, tribes, and other public entities. The loans are primarily for upgrading or expanding water pollution control facilities, such as public sewage and stormwater plants, and for activities to address nonpoint source water quality problems.

Coastal Zone Protection Fund

Since July 1998, water quality penalties issued under Chapter 90.48 RCW have been deposited into a sub-account of the Coastal Protection Fund (also referred to as Terry Husseman grants). A portion of this fund is made available to regional Ecology offices to support on-the-ground projects to perform environmental restoration and enhancement. Local governments, tribes, and state agencies must propose projects through Ecology staff. Stakeholders with projects that will reduce bacterial pollution are encouraged to contact their local TMDL coordinator to determine if their project proposal is a good candidate for Coastal Zone Protection funding.

Conservation Reserve Program (CRP)

The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Through CRP, landowners can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. Included under CRP is the Continuous Conservation Reserve Program (CCRP), which provides funds for special practices for both upland and riparian land. Landowners can enroll in CCRP at anytime. There are designated sign up periods for CCRP.

The Commodity Credit Corporation (CCC) makes annual rental payments based on the agriculture rental value of the land, and it provides cost-share assistance for 50 to 90% of the participant's costs in establishing approved conservation practices. Participants enroll in CRP contracts for 10 to 15 years.

The program is administered by the CCC through the Farm Service Agency (FSA), and program support is provided by Natural Resources Conservation Service, Cooperative State Research and Education Extension Service, state forestry agencies, and local Soil and Water Conservation Districts. (Farm Service Agency, 2006)

Environmental Quality Incentives Program (EQIP)

The federally funded Environmental Quality Incentives Program (EQIP) is administered by NRCS. EQIP is the combination of several conservation programs that address soil, water, and related natural resource concerns. EQIP encourages environmental enhancements on land in an environmentally beneficial and cost-effective manner. The EQIP program:

- Provides technical assistance, cost share, and incentive payments to assist crop and livestock producers with environmental and conservation improvements on the farm.
- Has 75% cost sharing but allows 90% if producer is a limited resource or beginning farmer.
- Divides program funding 60% for livestock-related practices, 40% for cropland.
- Has contracts lasting five to ten years.
- Has no annual payment limitation; sum not to exceed $450,000 per farm.

Wildlife Habitat Incentive Program

The Wildlife Habitat Incentive Program (WHIP) is administered by NRCS. WHIP is a voluntary program for people who want to develop and improve wildlife habitat primarily on private land. Through WHIP, NRCS provides both technical assistance and up to 75% cost-share assistance to establish and improve fish and wildlife habitat. WHIP agreements between NRCS and the participant generally last from five to ten years from the date the agreement is signed.

Conservation Security Program

The Conservation Security Program (CSP) is a voluntary program that provides financial and technical assistance to promote the conservation and improvement of soil, water, air, energy, plant and animal life, and other conservation purposes on tribal and private working lands. Working lands include cropland, grassland, prairie land, improved pasture, and range land, as well as forested land that is an incidental part of an agriculture operation. The program provides equitable access to benefits to all producers, regardless of size of operation, crops produced, or geographic location. CSP is administered by NRCS (NRCS, 2006).

Each year different watersheds are selected for CSP enrollment. It is not known when this program will come to the North Fork Palouse watershed. However, since the program rewards producers who already have conservation practices in place, producers are encouraged to use other federal, state, and local funding sources to prepare their land for enrollment (R. Riehle, NRCS 2006, per comm. March 17).

Housing Rehabilitation Loan Program

The Housing Rehabilitation Loan Program provides zero-interest and low-interest loans to residents to repair and improve the quality and safety of their homes. These loans can be used to repair and replace failing septic systems. Interest rates are based on household income. To qualify for this funding, homeowners must have an inspection performed for there residence and upgrade any other potential health risks that are identified.

Rural Housing Repair and Rehabilitation Loans

The Rural Housing Repair and Rehabilitation Loans are funded directly by the federal government. Loans are available to low-income rural residents who own and occupy a dwelling in need of repairs. Funds are available for repairs to improve or modernize a home, or to remove health and safety hazards such as a failing on-site system. This loan is a 1% loan that may be repaid over a 20-year period.

To obtain a loan, homeowner-occupants must have low income (defined as under 50% of the area median income), and be unable to obtain affordable credit elsewhere. They must need to make repairs and improvements to make the dwelling more safe and sanitary. Grants (up to $7,500) are available only to homeowners who are 62 years old or older and who cannot repay a Section 504 loan (USDA, 2006).

Wetland Reserve Program (WRP)

The Wetland Reserve Program (WRP) is a voluntary program administered by NRCS to restore and protect wetlands on private property (including farmland that has become a wetland as a result of flooding). The WRP provides technical and financial assistance to eligible landowners to address wetland, wildlife habitat, soil, water, and related natural resource concerns on private lands. The program offers three enrollment options: permanent easement, 30-year easement, and restoration cost-share agreement. Landowners receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land.

Under WRP, the landowner limits future use of the land, but retains ownership, controls access, and may lease the land for undeveloped recreational activities and possibly other compatible uses. Compatible uses are allowed if they are fully consistent with the protection and enhancement of the wetland.

Implementation Grant (Conservation Commission Grant)

The SCCD has an implementation grant from the Conservation Commission to provide cost-share funding for all farm plan approved BMPs.

County-Wide Riparian Cost-Share Buffer Program (Ecology Grant)

The SCCD has a cost-share program to help landowners to improve riparian areas, fence out livestock and provide off-creek watering, and revegetate stream sides.

Spokane River TMDL

The draft Managed Implementation Plan for the Spokane River Dissolved Oxygen recommends funding BMPs and other nonpoint source controls in the tributary watersheds.

Spokane County Conservation District SRF Program (Ecology Grant)

This funding program provides low interest loans to producers in the watershed for purchase of conservation equipment, such as direct seed drills. Increasing direct seed in the watershed will help reduce polluted runoff and erosion.

Summary of public involvement methods

The Hangman TMDL advisory committee was formed after two public meetings held in the watershed on March 24 and 25, 2004. Announcements were posted throughout the watershed, and 238 postcard announcements were sent to local businesses, towns, and residences that have indicated they were interested in Hangman water quality. The first public meeting was held in Fairfield, in the upper part of the watershed that is representative of agricultural and livestock landuses. The second public meeting was held in Marshall, in the lower part of the watershed and better represented the small acreage and urban landuses. From the list of interested persons generated at the two public meetings, an organizational meeting was held in Fairfield on April 29th, 2004. Workgroup meetings have been monthly, with the exception of some months that were skipped during harvest and/or for holidays or waiting for the completion of the load analysis.

Several agencies and land uses were represented at the meetings:

- Ecology
- City of Spokane
- Spokane County
- Coeur d'Alene Tribe
- Agricultural operators
- Timber operators
- Livestock operators
- Small acreage landowners
- Local community representatives

The local citizens and agency personnel have worked collaboratively to identify the water quality issues throughout the watershed and to propose workable BMPs and other solutions. Several of the activities to address these water quality issues not only cover the fecal coliform bacteria, turbidity, and temperature targeted by this TMDL but also are intended to reduce other nutrients and raise the dissolved oxygen.

The advisory committee, Ecology and SCCD have provided information on the TMDL at several local events. These include:

a. Presented summary of small acreage BMPs and review of *Implementation Strategy* to local landowner meeting. This meeting had approximately 12 local landowners in attendance.
b. Presented summary of agricultural BMPs and review of *Implementation Strategy* to local producer meeting. This meeting had over 250 local grower and producers in attendance.
c. Presented summary of livestock BMPs and issues to local watershed livestock owners. Approximately 35 persons attended the meeting.
d. Presented a display at the Southeast County fair in Rockford Washington.
e. Setup TMDL information booth at Fairfield Flag Day celebration and Tekoa Slippery Gulch Days.
f. Annually attended local city/town council meetings and gave brief presentation of TMDL project.

g. Presented a display at the Country Living Expo and the Ag Expo.
h. Provide articles for local Conservation District news letter.

A 30-day public comment period was held from __________ to __________2009. A press release announced the comment period and display ads were placed in _________________, ____________ and _____________ newspapers. Comments received are responded to in Appendix E.

Throughout the project development information has been available on the internet at www.ecy.wa.gov/programs/wq/tmdl/hangman_cr/index.html.

Next steps

Once EPA approves the TMDL, a *Water Quality Implementation Plan* (WQIP) must be developed within one year. Ecology and the SCCD will work with local people to create this plan, choosing the combination of possible solutions they think will be most effective in their watershed. Elements of this plan include:

- Who will commit to do what.
- How to determine if the implementation plan works.
- What to do if the implementation plan doesn't work.
- Potential funding sources.

In developing the WQIP, Ecology and the SCCD will ensure the plan addresses the recommendations made in the TMDL Analyses section of this report.

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Appendices

Appendix A. Glossary and Acronyms

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

7DAD: 7-day average daily maximum.

Ambient: Surrounding, encompassing, or natural conditions or environment.

Anadromous: Types of fish, such as salmon, that go from the sea to freshwater to spawn.

Anthropogenic: Human-caused.

Antidegradation: Cannot degrade the stream or system any further than what it is presently.

Aspect: Streamflow direction in decimal degrees from north.

Benthic: Assemblage of plants and animals living on the sea or stream bottom.

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Biological oxygen demand (BOD): The amount of oxygen concentration consumed by organic/biological organisms.

CAFO: Confined Animal Feeding Operation.

Clean Water Act: Federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the act establishes the TMDL program.

Concentration: The amount or mass of a substance or material in a given volume or mass of sample. Concentrations of fecal coliform bacteria are usually measured in colony forming units per 100 milliliters of water (Cfu/100 ml). Other parameters are usually measured in milligrams per liter (mg/ L), or parts per million (ppm), which are approximately equivalent at low concentration waters.

Cubic feet per second (cfs): Measure of water passing a point. The number of cubic feet that pass through a stream cross-section each second.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Diurnal: Daytime only, as opposed to nocturnal or crepuscular.

DMR: Discharge monitoring reports.

DO: Dissolved oxygen, a measure of the amount of oxygen dissolved in the water and available for aquatic organisms use.

Ecology: Washington State Department of Ecology.

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Effluent Dominated Stream: A stream that receives a greater volume of treated discharge water than would be in the stream without the discharge water. This would occur in streams with perennial flows, intermittent flows, and ephemeral flows. This may only occur seasonally during the critical period in some waters.

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis*, *S. faecium* , *S. gallinarum* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

EPA: U.S. Environmental Protection Agency.

Eutrophication: Enrichment of a lake's plant growth by an influx of excess nutrients required for the plant growth.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of nonself-replicating introduced native species, do not need to receive full support as an existing use.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from ten to 10,000 fold over a given period. The calculation is performed by: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

GIS: Geographic Information System

LSR: Little Spokane River.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Lognormal distribution: Let X be a random variable with a standard normal distribution. Then the variable $Y=e^X$ has a lognormal distribution. (For example, yearly incomes in the United States are roughly log-normally distributed.)

Macroinvertebrate: Organisms on or in the stream substrate that are visible with the naked eye.

Margin of safety (MOS): Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving waterbody.

mg/L: Milligrams per liter, approximately equal to parts per million in low concentration waters.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Ninetieth percentile (90^{th} percentile): An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90^{th} percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nth: A symbol used to generally define the last of the count of numbers in a set or series (e.g. 1, 2,3…N samples).

ODEQ: Oregon Department of Environmental Quality.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

pH: A measure of the acidity of a water, the negative log of the hydrogen ion concentration.

Point Source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

QAPP: Quality Assurance Project Plan, a document required by Ecology for water quality sampling.

Riparian: Transitional zone between aquatic and upland areas. The area has vegetation or other physical features reflecting permanent influence of surface or subsurface water.

River mile (RM): A measure of river or stream length starting at the mouth of the river or stream.

Salmonid: Belonging to the family *Salmonidae,* which includes salmon, trout and whitefishes.

SCCD: Spokane County Conservation District.

SNTEMP: Stream Network Temperature model.

Statistical rollback method: The statistical rollback method is an approach to working up environmental data that predicts pollutant concentrations after pollutant controls have been implemented.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands, and all other surface waters and water courses within the jurisdiction of Washington State.

System potential: The estimated water temperature if mature riparian vegetation and microclimate conditions were present with other available groundwater, channel improvement, and flow augmentation terms in place.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

TSS: Total suspended solids.

USGS: U.S. Geological Survey.

WAC: Washington Administrative Code.

WARMF: Watershed Analysis Risk Management Framework model.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Waste load allocations constitute one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Water Year (WY): Example: WY08 is October 1, 2007 through September 30, 2008.

W/M^2: Watts per square meter.

WRIA: Water Resource Inventory Area.

WRIA 56: Hangman Creek Water Resource Inventory Area.

WSDOT: Washington State Department of Transportation

Appendix B. Supplemental Information on Temperature

Overview of Stream Heating Processes

The temperature of a stream reflects the amount of heat energy in the water. Changes in water temperature within a particular segment of a stream are induced by the balance of the heat exchange between the water and the surrounding environment during transport through the segment. If there is more heat energy entering the water in a stream segment than there is leaving, the temperature will increase. If there is less heat energy entering the water in a stream segment than there is leaving, then the temperature will decrease. The general relationships between stream parameters, thermodynamic processes (heat and mass transfer), and stream temperature change are outlined in Figure B1.

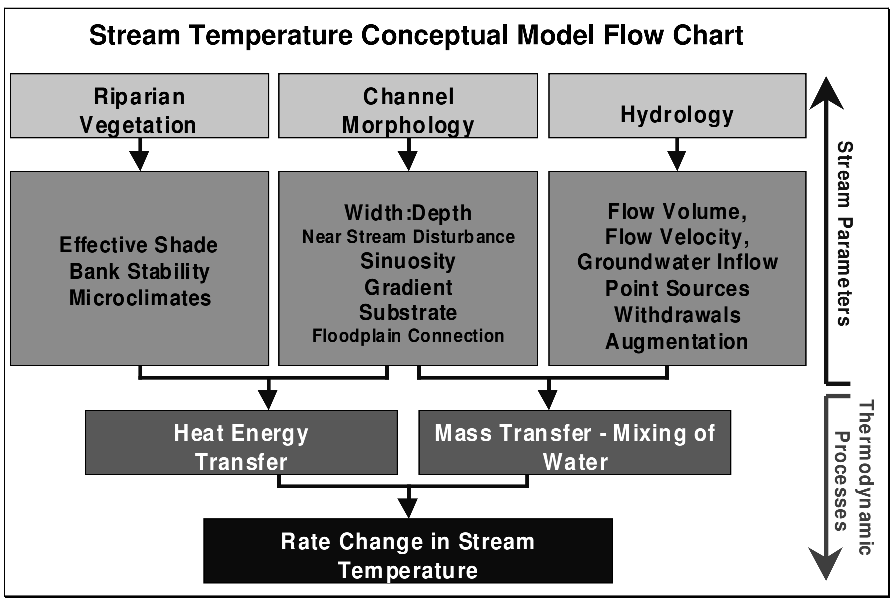

Figure B1. Conceptual model of factors that affect stream temperature.

Adams and Sullivan (1989) reported that the following environmental variables were the most important drivers of water temperature in forested streams:

- *Stream depth.* Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.
- *Air temperature.* Daily average stream temperatures and daily average air temperatures are both highly influenced by incoming solar radiation (Johnson, 2004). When the sun is not shining, the water temperature in a volume of water tends toward the dew-point temperature (Edinger et al., 1974).
- *Solar radiation and riparian vegetation.* The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily average temperatures are less affected by removal of riparian vegetation.
- *Groundwater.* Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream and the difference in temperatures between the groundwater and the stream.

Heat budgets and temperature prediction

Heat exchange processes occur between the waterbody and the surrounding environment, and control stream temperature. Edinger et al. (1974) and Chapra (1997) provide thorough descriptions of the physical processes involved. Figure B2 shows the major heat energy processes or fluxes across the water surface or streambed.

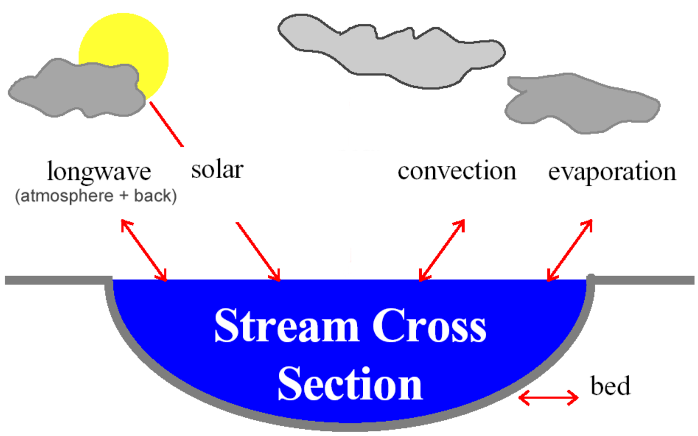

Figure B2. Surface heat exchange processes that affect water temperature (net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed). Heat flux between the water and streambed occurs through conduction and hyporheic exchange.

The heat exchange processes with the greatest magnitude are as follows (Edinger et al., 1974):

- **Shortwave solar radiation**. Shortwave solar radiation is the radiant energy which passes directly from the sun to the earth. Shortwave solar radiation is contained in a wavelength range between 0.14 μm and about 4 μm. The peak values during daylight hours are typically about 3 times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.
- **Longwave atmospheric radiation.** The longwave radiation from the atmosphere ranges in wavelength from about 4 to 120 μm. Longwave atmospheric radiation depends primarily on air temperature and humidity and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al., 1974).
- **Longwave back radiation from the water to the atmosphere.** Water sends heat energy back to the atmosphere in the form of long-wave radiation in the wavelength range from about 4 to 120 μm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from longwave back radiation typically ranges from about 300 to 500 W/m^2 (Edinger et al., 1974).

The remaining heat exchange processes generally have less magnitude and are as follows:

- **Evaporation flux at the air-water interface** is influenced mostly by the wind speed and the vapor pressure gradient between the water surface and the air. When the air is saturated, the evaporation stops. When the gradient is negative (vapor pressure at the water surface is less than the vapor pressure of the air), condensation, the reversal of evaporation, takes place. This term then becomes a gain component in the heat balance.
- **Convection flux at the air-water interface** is driven by the temperature difference between water and air and by the wind speed. Heat is transferred in the direction of decreasing temperature.
- **Bed conduction flux and hyporheic exchange** component of the heat budget represents the heat exchange through conduction between the bed and the waterbody and the influence of hyporheic exchange. The magnitude of bed conduction is driven by the size and conductance properties of the substrate. The heat transfer through conduction is more pronounced when thermal differences between the substrate and water column are higher and usually affects the temperature diel profile, rather than affecting the magnitude of the maximum daily water temperature.

  Hyporheic exchange recently received increased attention as a possible important mechanism for stream cooling (Johnson and Jones, 2000, Poole and Berman, 2000, Johnson, 2004). The hyporheic zone is defined as the region located beneath the channel characterized by complex hydrodynamic processes that combine stream water and groundwater. The resulting fluxes can have significant implications for stream temperature at different spatial and temporal scales.

The bulk temperature of a vertically mixed volume of water in a stream segment under natural conditions tends to increase or decrease with time during the day according to whether the net heat flux is positive or negative. When the sun is not shining, the water temperature tends toward the dew-point temperature (Edinger et al., 1974; Brady et al., 1969). The equilibrium temperature of a natural body of water is defined as the temperature at which the water is in equilibrium with its surrounding environment and the net rate of surface heat exchange would be zero (Edinger et al., 1968; 1974).

The dominant contribution to the seasonal variations in the equilibrium temperature of water is from seasonal variations in the dew-point temperature (Edinger et al., 1974). The main source of hourly fluctuations in water temperature during the day is solar radiation. Solar radiation generally reaches a maximum during the day when the sun is highest in the sky unless cloud cover or shade from vegetation interferes.

The complete heat budget for a stream also accounts for the mass transfer processes which depend on the amount of flow and the temperature of water flowing into and out of a particular volume of water in a segment of a stream. Mass transfer processes in open channel systems can occur through advection, dispersion, and mixing with tributaries and groundwater inflows and outflows. Mass transfer relates to transport of flow volume downstream, instream mixing, and the introduction or removal of water from a stream. For instance, flow from a tributary will cause a temperature change if the temperature is different from the receiving water.

Thermal role of riparian vegetation

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation is well documented (*e.g.,* Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982; Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2M Hill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature. The list of important benefits that riparian vegetation has on the stream temperature includes:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.
- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.

- Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land-cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris, and influencing sedimentation, stream substrate compositions, and streambank stability.

The warming of water temperatures as a stream flows downstream is a natural process. However, the rates of heating can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. There is a natural maximum level of shade that a given stream is capable of attaining, and the importance of shade decreases as the width of a stream increases.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Effective shade

Shade is an important parameter that controls the stream heating derived from solar radiation. Solar radiation has the potential to be one of the largest heat-transfer mechanisms in a stream system. Human activities can degrade near-stream vegetation and/or channel morphology, and in turn, decrease shade. Reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Stream shade is an important factor in describing the heat budget for the present analysis. Stream shade may be measured or calculated using a variety of methods (Chen, 1996; Chen et al., 1998; Ice, 2001; OWEB, 1999; Teti, 2001; Teti and Pike, 2005).

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography, above a stream. Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

$$\text{effective shade} = (J_1 - J_2)/J_1$$

where J_1 is the potential solar heat flux above the influence of riparian vegetation and topography, and J_2 is the solar heat flux at the stream surface.

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summer months, allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun) (Figure B3). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation (direction of streamflow). Near-stream vegetation height, width, and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e., produce shade) (Table B1). The solar position has a vertical component (i.e., solar altitude) and a horizontal component (i.e., solar azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation.

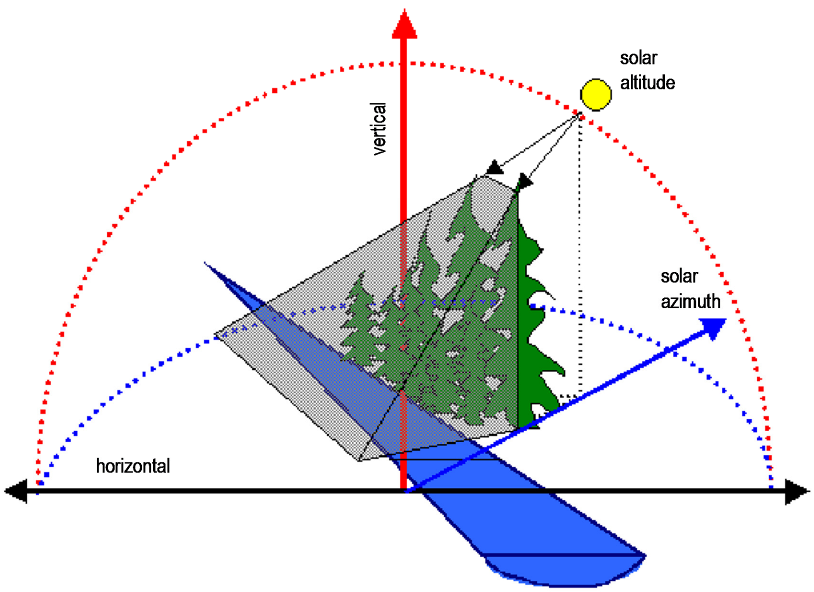

Figure B3. Parameters that affect shade and geometric relationships. Solar altitude is a measure of the vertical angle of the sun's position relative to the horizon. Solar azimuth is a measure of the horizontal angle of the sun's position relative to north.

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including (Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005):

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers (ACD) and Solar pathfinders provide a good balance of cost and accuracy for measuring the importance of riparian vegetation for preventing increases in stream temperature (Teti, 2001; Beschta et al., 1987; Teti, 2005). Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the ACD is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 a.m. and 2 p.m. in mid-to-late summer) when the potential solar heat flux is most significant. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80% to 90%.

Computer programs for the mathematical simulation of shade may also be used to estimate shade from measurements or estimates of the key parameters listed in Table B1 (Ecology, 2003a; Chen, 1996; Chen et al., 1998; Boyd, 1996; Boyd and Park, 1998).

Table B1. Factors that influence stream shade (bold indicates influenced by human activities).

Description	Parameter
Season/time	Date/time
Stream characteristics	Aspect, **channel width**
Geographic position	Latitude, longitude
Vegetative characteristics	**Riparian vegetation height, width, and density**
Solar position	Solar altitude, solar azimuth

Riparian buffers and effective shade

Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure B4).

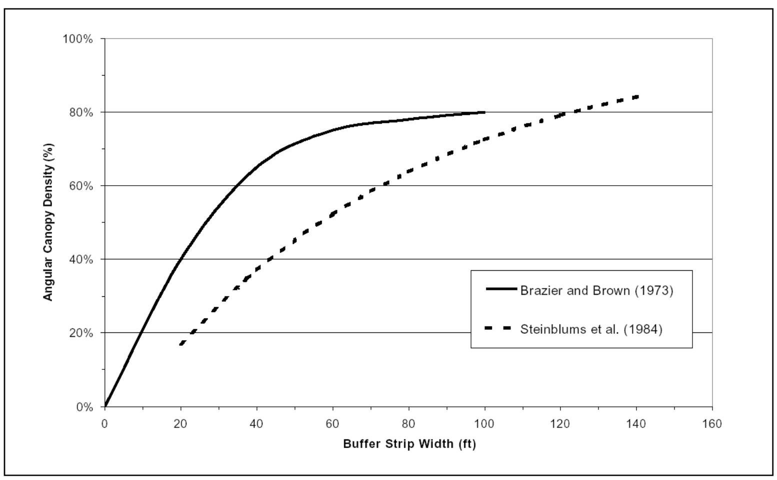

Figure B4. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands (after Beschta et al., 1987 and CH2M Hill, 2000).

The shade as represented by angular canopy density (ACD) for a given riparian buffer width varies over space and time because of differences among site-potential vegetation, forest development stages (e.g., height and density), and stream width. For example, a 50-foot-wide riparian area with fully developed trees could provide from 45 to 72 % of the potential shade in the two studies shown in Figure B4.

The Brazier and Brown (1973) shade data show a stronger relationship between ACD and buffer strip width than the Steinblums et al. (1984) data: the r^2 correlation for ACD and buffer width was 0.87 and 0.61 in Brazier and Brown (1973) and Steinblums et al. (1984), respectively. This difference supports the use of the Brazier and Brown curve as a base for measuring shade effectiveness under various riparian buffer proposals. These results reflect the natural variation among old-growth sites studied, and show a possible range of potential shade.

Several studies of stream shading report that most of the potential shade comes from the riparian area within about 75 feet (23 meter) of the channel (CH2M Hill, 2000; Castelle and Johnson, 2000):

- Beschta et al. (1987) report that a 98-foot (30-meter) buffer provides the same level of shading as that of an old-growth stand.
- Brazier and Brown (1973) found that a 79-foot (24-meter) buffer would provide maximum shade to streams.
- Steinblums et al. (1984) concluded that a 56-foot (17-meter) buffer provides 90% of the maximum ACD.
- Corbett and Lynch (1985) concluded that a 39-foot (12-meter) buffer should adequately protect small streams from large temperature changes following logging.
- Broderson (1973) reported that a 49-foot (15-meter) buffer provides 85% of the maximum shade for small streams.
- Lynch et al. (1984) found that a 98-foot (30-meter) buffer maintains water temperatures within 2°F (1°C) of their former average temperature in small streams (channel width less than 3 meters).

GEI (2002) reviewed the scientific literature related to the effectiveness of buffers for shade protection in agricultural areas in Washington. They concluded that buffer widths of 10 meters (33 feet) provide nearly 80% of the maximum potential shade in agricultural areas. Wenger (1999) concluded that a minimum continuous buffer width of 10-30 meters should be preserved or restored along each side of all streams on a municipal or county-wide scale to provide stream temperature control and maintain aquatic habitat. GEI (2002) considered the recommendations of Wenger (1999) to be relevant for agricultural areas in Washington.

Steinblums et al. (1984) concluded that shade could be delivered to forest streams from beyond 75 feet (22 meters) and potentially out to 140 feet (43 meters). In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively low. This is because the potential solar radiation decreases significantly as solar elevation decreases.

Microclimate - surrounding thermal environment

A secondary consequence of near-stream vegetation is its effect on the riparian microclimate. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity, and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures. Relative humidity increases result from the evapotranspiration that is occurring by riparian plant communities. Wind speed is reduced by the physical blockage produced by riparian vegetation.

Riparian buffers commonly occur on both sides of the stream, compounding the edge influence on the microclimate. Brosofske et al. (1997) reported that a buffer width of at least 150 feet (45 meters) on each side of the stream was required to maintain a natural riparian microclimate environment in small forest streams (channel width less than 4 meters) in the foothills of the western slope of the Cascade Mountains in western Washington with predominantly Douglas Fir and Western Hemlock.

Bartholow (2000) provided a thorough summary of literature of documented changes to the environment of streams and watersheds associated with extensive forest clearing. Changes summarized by Bartholow (2000) are representative of hot summer days and indicate the mean daily effect unless otherwise indicated:

- **Air temperature**. Edgerton and McConnell (1976) showed that removing all or a portion of the tree canopy resulted in cooler terrestrial air temperatures at night and warmer temperatures during the day, enough to influence thermal cover sought by elk (Cervus canadensis) on their eastern Oregon summer range. Increases in maximum air temperature varied from 5 to 7ºC for the hottest days (estimate). However, the mean daily air temperature did not appear to have changed substantially since the maximum temperatures were offset by almost equal changes to the minima.

  Similar temperatures have been commonly reported (Childs and Flint, 1987; Fowler et al., 1987), even with extensive clearcuts (Holtby, 1988). In an evaluation of buffer strip width, Brosofske et al. (1997) found that air temperatures immediately adjacent to the ground increased 4.5ºC during the day and about 0.5ºC at night (estimate). Fowler and Anderson (1987) measured a 0.9ºC air temperature increase in clearcut areas, but temperatures were also 3ºC higher in the adjacent forest. Chen et al. (1993) found similar (2.1ºC) increases.

  All measurements reported here were made over land instead of water, but in aggregate support about a 2ºC increase in ambient mean daily air temperature resulting from extensive clearcutting.

- **Relative humidity**. Brosofske et al. (1997) examined changes in relative humidity within 17 to 72-meter buffer strips. The focus of their study was to document changes along the gradient from forested to clearcut areas, so they did not explicitly report pre- to post-harvest changes at the stream. However, there appeared to be a reduction in relative humidity at the stream of 7% during the day and 6% at night (estimate). Relative humidity at stream sites increased exponentially with buffer width. Similarly, a study by Chen et al. (1993) showed a decrease of about 11% in mean daily relative humidity on clear days at the edges of clearcuts.

- **Wind speed**. Brosofske et al. (1997) reported almost no change in wind speed at stream locations within buffer strips adjacent to clearcuts. Speeds quickly approached upland conditions toward the edges of the buffers, with an indication that wind actually increased substantially at distances of about 15 meters from the edge of the strip, and then declined farther upslope to pre-harvest conditions. Chen et al. (1993) documented increases in both peak and steady winds in clearcut areas; increments ranged from 0.7 to 1.2 meter/s (estimated).

Thermal role of channel morphology

Changes in channel morphology (widening) impacts stream temperatures. As a stream widens, the surface area exposed to heat flux increases, resulting in increased energy exchange between a stream and its environment (Chapra, 1997). Further, wide channels are likely to have decreased levels of shade due to the increased distance created between vegetation and the wetted channel, and the decreased fraction of the stream width that could potentially be covered by shadows from riparian vegetation. Conversely, narrow channels are more likely to experience higher levels of shade.

Channel widening is often related to degraded riparian conditions that allow increased streambank erosion and sedimentation of the streambed, both of which correlate strongly with riparian vegetation type and condition (Rosgen, 1996). Channel morphology is not solely dependent on riparian conditions. Sedimentation can deposit material in the channel, fill pools, and aggrade the streambed, reducing channel depth and increasing channel width.

Channel modification usually occurs during high-flow events. Land uses that affect the magnitude and timing of high-flow events may negatively impact channel width and depth. Riparian vegetation conditions will affect the resilience of the streambanks/flood plain during periods of sediment introduction and high flow. Disturbance processes may have differing results depending on the ability of riparian vegetation to shape and protect channels. Channel morphology is related to riparian vegetation composition and condition by:

- **Building streambanks**. Traps suspended sediments, encourages deposition of sediment in the flood plain, and reduces incoming sources of sediment.
- **Maintaining stable streambanks**. High rooting strength and high streambank and flood plain roughness prevent streambank erosion.
- **Reducing flow velocity** (erosive kinetic energy). Supplies large woody debris to the active channel, provides a high pool-to-riffle ratio and adds channel complexity that reduces shear stress exposure to streambank soil particles.

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Pollutants and Surrogate Measures

Heat loads to the stream are calculated in this TMDL in units of calories per square centimeter per day ($cal/cm^2/day$) or watts per square meter (W/m^2). However, heat loads are of limited value in guiding management activities needed to solve identified water quality problems.

The Hangman Creek temperature TMDL incorporates measures other than “daily loads” to fulfill the requirements of Section 303(d). This TMDL allocates other appropriate measures, or “surrogate measures,” as provided under EPA regulations [40 CFR 130.2(i)]. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

“When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional “pollutant,” the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not.”

This technical assessment for the Hangman Creek temperature TMDL uses riparian effective shade as a surrogate measure of heat flux to fulfill the requirements of Section 303(d). Effective shade is defined as the fraction of the potential solar shortwave radiation that is blocked by vegetation and topography before it reaches the stream surface. Other factors influencing heat flux and water temperature were also considered, including microclimate, channel geometry, groundwater recharge, and instream flow.

Table B2. Spokane County Conservation District densiometer measurements taken on Hangman Creek, September 20 – 22, 2006.

Site No.	RM	Left Bank				Center Channel				Right Bank				Shade estimate		
		up	left	down	right	up	left	down	right	up	left	down	right	Average	x 1.04	
		72	92	86	48	0	0	0	2	96	88	96	92	56.0	58.2	
		4	8	84	32	0	0	0	20	92	0	48	72	30.0	31.2	
		16	46	4	10	5	0	0	34	96	92	96	96	41.3	42.9	
1	RM 0.6	0	2	0	5	4	0	2	5	56	6	13	96	15.8	16.4	**27.0**
		0	0	0	10	2	0	2	25	35	4	22	32	11.0	11.4	
		0	12	0	4	0	0	0	16	76	12	40	30	15.8	16.5	
		1	19	1	2	0	0	0	10	8	18	48	32	11.6	12.0	
		15	2	0	0	0	1	0	0	0	12	12	48	7.5	7.8	
		0	12	0	0	0	2	0	3	96	96	45	6	21.7	22.5	
		0	0	0	1	0	0	0	1	0	0	0	22	2.0	2.1	
2	RM 3.6	0	0	0	3	0	0	0	1	0	0	8	17	2.4	2.5	**13.7**
		0	0	0	0	0	0	0	2	0	0	0	0	0.2	0.2	
		0	6	49	0	0	0	0	0	96	96	96	96	36.6	38.0	
		50	92	86	5	0	0	0	0	4	4	8	16	22.1	23.0	
		0	38	6	0	0	0	0	0	0	0	0	10	4.5	4.7	
		8	72	43	2	0	0	0	0	0	0	0	0	10.4	10.8	
		24	32	32	12	0	0	0	0	0	0	0	0	8.3	8.7	
3	RM 4.5	60	25	0	0	0	4	0	0	0	0	0	0	7.4	7.7	**5.5**
		0	44	4	0	0	0	0	0	0	0	0	0	4.0	4.2	
		0	10	18	0	0	0	0	0	0	0	0	0	2.3	2.4	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		46	10	44	6	3	7	3	14	12	6	14	54	18.3	19.0	
		96	96	96	96	6	12	3	38	96	96	96	96	68.9	71.7	
		0	3	0	8	7	6	7	26	38	0	18	72	15.4	16.0	
4	RM 5.7	96	92	90	0	0	0	0	8	2	0	0	14	25.2	26.2	**26.0**
		42	88	2	0	0	18	0	3	1	13	18	11	16.3	17.0	
		4	4	4	9	0	2	0	27	0	1	3	38	7.7	8.0	
		0	8	0	9	0	2	2	28	44	24	76	88	23.4	24.4	
		28	48	0	0	2	0	0	10	25	0	2	5	10.0	10.4	
		2	8	2	0	0	0	0	0	0	0	0	0	1.0	1.0	
		0	86	18	0	0	0	0	0	0	0	0	0	8.7	9.0	
5	RM 8.8	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	**5.7**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	70	32	21	84	17.3	17.9	
		0	0	0	0	0	2	3	7	0	0	3	0	1.3	1.3	
		0	34	6	0	0	4	0	0	0	0	0	0	3.7	3.8	
		0	0	0	0	0	0	0	0	10	0	0	0	0.8	0.9	
		0	11	0	0	0	0	0	0	0	0	0	0	0.9	1.0	

Site No.	RM	Left Bank				Center Channel				Right Bank				Shade estimate		
		up	left	down	right	up	left	down	right	up	left	down	right	Average	x 1.04	
6	RM 13.8	34	16	0	0	0	0	0	4	0	0	0	0	4.5	4.7	**1.5**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
7	RM 18.2	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	**2.9**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		10	20	10	0	0	0	2	38	27	0	46	85	19.8	20.6	
		1	30	2	26	18	0	6	18	50	0	14	59	18.7	19.4	
		0	6	0	12	2	0	10	42	60	12	44	92	23.3	24.3	
		6	52	12	0	0	7	0	6	10	0	9	26	10.7	11.1	
8	RM 18.7	32	0	0	28	0	0	0	0	12	0	8	52	11.0	11.4	**12.3**
		0	0	0	0	0	0	0	0	84	17	5	78	15.3	15.9	
		4	8	0	0	0	0	0	0	0	0	0	0	1.0	1.0	
		14	21	0	0	0	0	0	0	0	0	0	0	2.9	3.0	
		6	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	16	2	0	0	0	0	0	0	0	0	0	1.5	1.6	
9	RM 20.2	3	7	0	0	0	0	0	0	0	0	0	0	0.8	0.9	**0.4**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
10	RM 22.5	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	**0.4**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		23	7	3	0	0	2	0	0	0	0	0	0	2.9	3.0	
		0	0	0	0	0	0	0	2	2	0	0	18	1.8	1.9	
		0	2	0	0	0	0	0	2	8	0	0	0	1.0	1.0	
		0	3	1	0	0	2	0	3	10	0	12	38	5.8	6.0	
11	RM 29.2	2	7	0	2	0	0	4	8	66	7	61	96	21.1	21.9	**9.4**
		2	15	0	4	0	8	2	24	20	0	26	55	13.0	13.5	
		0	4	0	3	6	0	7	12	17	0	15	28	7.7	8.0	
		6	0	0	0	2	2	12	21	27	1	42	46	13.3	13.8	
		21	0	0	0	2	2	0	0	0	0	0	0	2.1	2.2	

Site No.	RM	Left Bank				Center Channel				Right Bank				Shade estimate		
		up	left	down	right	up	left	down	right	up	left	down	right	Average	x 1.04	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	1	2	0	0	0	3	4	96	0	58	32	16.3	17.0	
12	RM 31	0	20	0	2	5	0	0	6	25	0	0	0	4.8	5.0	**4.1**
		1	0	0	0	0	2	0	0	15	0	0	34	4.3	4.5	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	8	0.7	0.7	
		0	0	0	0	0	0	0	0	0	0	0	18	1.5	1.6	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
13	RM 32.9	0	0	0	0	0	0	0	0	0	0	0	6	0.5	0.5	**2.2**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		8	7	0	0	0	0	0	0	0	4	24	4	3.9	4.1	
		2	29	25	0	0	22	0	0	10	13	0	0	8.4	8.8	
		96	96	96	88	0	0	0	24	0	2	0	0	33.5	34.8	
		0	22	2	0	0	0	0	0	0	6	0	0	2.5	2.6	
		20	92	34	0	0	26	15	0	0	13	0	0	16.7	17.3	
14	RM 35.5	8	16	0	0	2	8	2	0	0	1	8	0	3.8	3.9	**9.4**
		6	24	0	0	0	6	0	0	0	7	1	0	3.7	3.8	
		0	24	0	0	0	4	0	0	0	6	0	0	2.8	2.9	
		0	2	0	0	0	0	0	0	0	0	0	0	0.2	0.2	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
15	RM 37	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	**0.0**
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	
		0	0	2	0	0	0	0	2	0	4	0	0	0.7	0.7	
		4	12	7	0	8	10	2	0	24	0	12	92	14.3	14.8	
		0	15	1	3	0	0	0	0	0	0	16	32	5.6	5.8	
16	RM 38	6	2	1	2	2	6	0	3	0	0	0	14	3.0	3.1	**7.5**
		3	3	6	7	0	2	0	8	8	2	2	26	5.6	5.8	
		1	4	0	0	0	0	0	0	12	0	18	26	5.1	5.3	
		3	6	4	0	0	0	0	0	12	1	80	92	16.5	17.2	
		16	64	22	0	4	8	0	8	15	5	14	56	17.7	18.4	
		16	38	2	0	0	12	0	0	5	1	1	12	7.3	7.5	
		0	8	2	12	0	8	2	12	6	1	0	2	4.4	4.6	
17	RM 39.5	0	22	0	0	2	4	0	2	1	2	5	7	3.8	3.9	**9.5**
		0	38	12	0	0	20	16	4	0	6	1	9	8.8	9.2	
		20	81	20	0	4	34	3	6	0	20	1	2	15.9	16.6	
		1	11	4	0	0	10	0	0	1	2	1	44	6.2	6.4	

Site No.	RM	Left Bank				Center Channel				Right Bank				Shade estimate		
		up	left	down	right	up	left	down	right	up	left	down	right	Average	x 1.04	
		1	5	0	6	0	0	0	0	0	0	1	0	1.1	1.1	
		0	0	4	2	0	0	0	0	3	1	0	0	0.8	0.9	
		12	54	10	0	0	0	0	0	0	0	0	0	6.3	6.6	
18	RM 41.6	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	**1.9**
		0	0	0	0	0	0	0	0	0	1	0	0	0.1	0.1	
		0	0	0	0	0	8	8	8	0	0	0	0	2.0	2.1	
		2	4	10	8	0	0	0	0	0	2	0	0	2.2	2.3	
		2	52	44	0	0	2	0	0	0	0	0	3	8.6	8.9	
		56	96	48	4	0	16	0	0	4	6	15	16	21.8	22.6	
		18	26	2	0	0	4	0	13	68	4	8	66	17.4	18.1	
19	RM 47	30	80	4	4	2	24	0	5	6	2	13	75	20.4	21.2	**18.4**
		36	84	48	10	0	0	0	5	15	0	1	41	20.0	20.8	
		48	80	30	4	0	8	4	10	15	3	18	89	25.8	26.8	
		4	20	2	0	7	0	0	9	48	0	0	32	10.2	10.6	

Table B3. Effective shade and solar radiation outcomes for various combinations of stream metrics (width and aspect) based on Hangman Creek maximum system-potential vegetation estimates.

Bankfull width (m)	Effective shade from vegetation (percent) at the stream center at various stream aspects (degrees from N)			Daily average global solar short-wave radiation (W/m2) at the stream center at various stream aspects (degrees from N)		
	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect	0 and 180 deg aspect	45, 135, 225, and 315 deg aspect	90 and 270 deg aspect
1	97.6%	97.7%	98.1%	7	7	6
2	92.0%	92.3%	95.7%	24	23	13
3	84.7%	84.8%	90.1%	47	46	30
4	78.2%	77.5%	77.5%	66	68	68
5	72.5%	71.2%	67.0%	84	88	100
6	67.3%	65.8%	57.5%	100	104	129
7	62.8%	61.0%	49.9%	113	119	152
8	59.0%	56.9%	44.2%	125	131	170
9	55.6%	53.3%	39.7%	135	142	183
10	52.6%	50.1%	36.1%	144	152	194
12	47.3%	44.6%	30.6%	160	169	211
14	42.9%	40.1%	26.7%	174	182	223
16	39.2%	36.4%	23.7%	185	194	232
18	36.1%	33.3%	21.4%	194	203	239
20	33.4%	30.6%	19.5%	203	211	245
25	28.1%	25.5%	16.0%	219	227	255
30	24.2%	21.8%	13.7%	231	238	263
35	21.3%	19.1%	12.0%	240	246	268
40	18.9%	16.9%	10.6%	247	253	272
45	17.1%	15.2%	9.6%	252	258	275
50	15.5%	13.8%	8.7%	257	262	278
55	14.2%	12.6%	8.0%	261	266	280
60	13.1%	11.6%	7.4%	264	269	282

Table B4. Hangman Creek heat load allocations and shade requirements by kilometer from the Idaho-Washington border to the mouth.

Distance from upstream segment boundary (Km)	Distance to downstream segment boundary (Km)	Current shade condition (%)	System potential shade	Increase in % shade needed	Landmark river mile station	Load allocation for daily average shortwave solar radiation on August 1 (watts/m2)
1	2	21%	56%	35%		137.5
2	3	27%	67%	40%		102.0
3	4	23%	66%	43%		106.3
4	5	11%	47%	36%		166.7
5	6	18%	59%	41%		128.9
6	7	20%	58%	38%	ID-WA border	131.3
7	8	25%	52%	27%		149.6
8	9	22%	54%	32%		144.4
9	10	22%	54%	32%		143.6
10	11	11%	45%	34%	Tekoa	172.9
11	12	19%	60%	41%	Little Hangman	125.8
12	13	18%	56%	37%	Tekoa	139.1
13	14	26%	68%	42%		100.3
14	15	30%	67%	37%		104.0
15	16	19%	62%	43%		119.8
16	17	14%	43%	29%		179.7
17	18	11%	48%	37%		162.0
18	19	9%	39%	30%		191.0
19	20	17%	50%	33%		155.3
20	21	27%	43%	17%		178.0
21	22	11%	47%	36%		167.0
22	23	18%	49%	31%	Cove Creek	160.4
23	24	15%	44%	29%	Latah	176.5
24	25	11%	46%	34%		170.4
25	26	12%	47%	35%		165.5
26	27	9%	42%	33%		180.7
27	28	9%	39%	30%		189.9
28	29	10%	35%	25%		203.3
29	30	14%	53%	39%		147.8
30	31	7%	21%	14%		247.1
31	32	14%	41%	27%		186.1
32	33	14%	47%	33%		166.5
33	34	7%	25%	17%		236.0
34	35	7%	37%	30%		196.9
35	36	10%	41%	31%		184.7
36	37	4%	24%	20%	Waverly	239.1
37	38	9%	39%	30%		192.1
38	39	7%	21%	14%		247.1
39	40	18%	54%	37%		142.4
40	41	9%	29%	20%		221.6
41	42	11%	45%	33%		173.5
42	43	7%	33%	26%		209.6

Distance from upstream segment boundary (Km)	Distance to downstream segment boundary (Km)	Current shade condition (%)	System potential shade	Increase in % shade needed	Landmark river mile station	Load allocation for daily average shortwave solar radiation on August 1 (watts/m2)
43	44	14%	44%	31%		173.8
44	45	5%	21%	16%	Rattler Run	247.4
45	46	6%	26%	20%		231.4
46	47	7%	31%	24%		214.4
47	48	5%	31%	25%		216.2
48	49	7%	32%	25%		212.2
49	50	12%	33%	21%		209.7
50	51	17%	37%	20%		197.8
51	52	11%	21%	10%		247.5
52	53	22%	29%	7%		221.8
53	54	28%	48%	19%		163.5
54	55	19%	33%	15%		207.9
55	56	20%	37%	17%		196.5
56	57	16%	44%	28%		175.8
57	58	7%	33%	26%		209.3
58	59	9%	39%	29%		190.5
59	60	13%	43%	30%		177.4
60	61	23%	59%	36%		127.3
61	62	16%	42%	26%		180.7
62	63	6%	30%	24%	Latah Road	219.0
63	64	6%	23%	18%		239.3
64	65	10%	23%	13%		240.4
65	66	12%	24%	12%	Rock Creek	236.4
66	67	5%	29%	24%	Spangle Creek	221.9
67	68	13%	34%	21%	Duncan Road	206.6
68	69	10%	34%	24%	California Creek	206.3
69	70	17%	35%	18%		203.3
70	71	8%	35%	27%		202.7
71	72	16%	50%	34%		156.4
72	73	13%	38%	25%		194.6
73	74	14%	31%	17%		215.1
74	75	14%	45%	30%		172.0
75	76	7%	28%	21%		225.2
76	77	11%	29%	18%	Hangman Val. GC	222.1
77	78	9%	34%	26%		204.3
78	79	7%	21%	14%		245.9
79	80	9%	22%	13%		243.9
80	81	14%	38%	23%		193.4
81	82	7%	28%	21%		223.1
82	83	16%	41%	24%		184.1
83	84	12%	33%	21%		207.2
84	85	13%	39%	27%		188.7
85	86	6%	23%	18%		239.1
86	87	26%	37%	11%		195.9

Distance from upstream segment boundary (Km)	Distance to downstream segment boundary (Km)	Current shade condition (%)	System potential shade	Increase in % shade needed	Landmark river mile station	Load allocation for daily average shortwave solar radiation on August 1 (watts/m2)
87	88	27%	42%	15%		180.5
88	89	9%	39%	29%		191.2
89	90	11%	24%	13%		237.2
90	91	14%	32%	18%	Marshall Creek	212.4
91	92	26%	45%	19%		171.8
92	93	19%	50%	32%		154.3
93	94	23%	56%	33%		136.0
94	95	18%	56%	38%		136.9
95	96	19%	48%	29%	USGS Gage	161.9
96	97	22%	31%	10%		213.0
97	97.6	6%	14%	7%		268.6

Appendix C. Supplemental Information on Models

Statistical Theory of Rollback

The statistical rollback method proposed by Ott (1995) describes a way to use a numeric distribution of a water quality parameter to estimate the distribution after abatement processes are applied to sources. The method relies on basic dispersion and dilution assumptions and their effect on the distribution of a chemical or a bacterial population at a monitoring site downstream from a source. It then provides a statistical estimate of the new population after a chosen reduction factor is applied to the existing pollutant source. In the case of the Total Maximum Daily Load (TMDL), compliance with the most restrictive of the dual fecal coliform (FC) criteria will determine the reduction factor needed.

As with many water quality parameters, FC counts collected over time at an individual site usually follow a lognormal distribution. That is, over the course of sampling for a year, or multiple years, most of the counts are low, but a few are much higher. When monthly FC data are plotted on a logarithmic-probability graph (the open diamonds in Figure C1), they appear to form nearly a straight line.

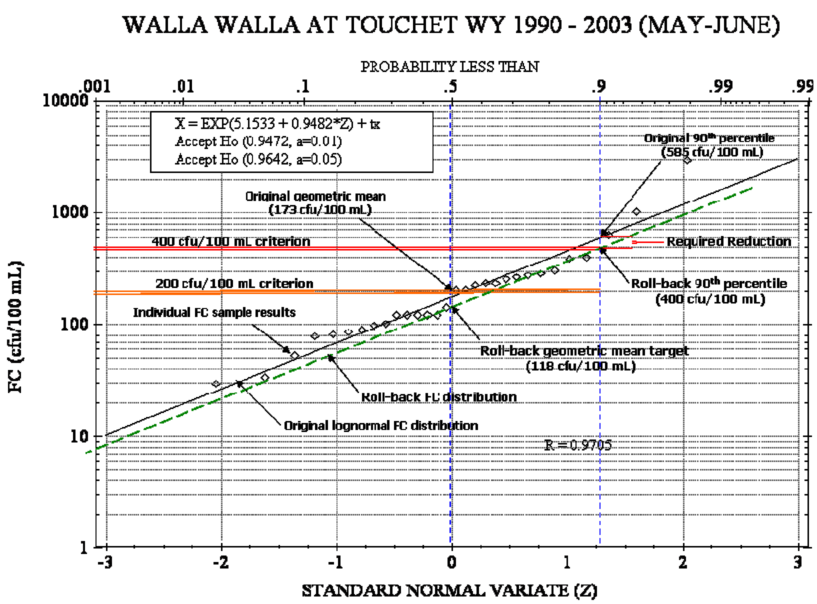

Figure C1. Graphical depiction of the statistical rollback method for fecal coliform targets.

The 50th percentile (an estimate of the geometric mean) and the 90th percentile (a representation of the level over which 10% of the samples lie) can be located along a line plotted from an equation estimating the original monthly FC data distribution.

In Figure C1, these numbers are 173 cfu/100 mL and 585 cfu/100 mL, respectively. Using the statistical rollback method, the 90th percentile value is then reduced to 400 cfu/100 mL (*Secondary Contact Recreation* 90th percentile criterion), since 173 cfu/100 mL meets the *Secondary Contact* geometric mean criterion. The new distribution is plotted parallel to the original. The estimate of the geometric mean for this new distribution, located at the 50th percentile, is 118 cfu/100 mL. The result is a geometric mean target of a sample distribution that would likely have less than 10% of its samples over 400 cfu/100 mL. A 32% FC reduction is required from combined sources to meet this target distribution from the simple calculation: (585 - 400) / 585 = 0.316 * 100 = 31.6% (rounded to 32%).

The following is a summary of the major theorems and corollaries for the Statistical Theory of Rollback (STR) from *Environmental Statistics and Data Analysis* by Ott (1995).

1. If Q = the concentration of a contaminant at a source, and D = the dilution-diffusion factor, and X = the concentration of the contaminant at the monitoring site, then X = Q*D.
2. Successive random dilution and diffusion of a contaminant Q in the environment often result in a lognormal distribution of the contaminant X at a distant monitoring site.
3. The coefficient of variation (CV) of Q is the same before and after applying a "rollback" (i.e., the CV in the post-control state will be the same as the CV in the pre-control state). The rollback factor = r, a reduction factor expressed as a decimal (a 70% reduction would be a rollback factor of 0.3). The random variable Q represents a pre-control source output state, and rQ represents the post-control state.
4. If D remains consistent in the pre-control and post-control states (long-term hydrological and climatic conditions remain unchanged), then CV(Q)*CV(D)=CV(X), and CV(X) will be the same before and after the rollback is applied.
5. If X is multiplied by the rollback factor, then the variance in the post-control state will be multiplied by r^2, and the post-control standard deviation will be multiplied by r.
6. If X is multiplied by the rollback factor, the quantiles of the concentration distribution will be scaled geometrically.
7. If any random variable is multiplied by r, then its expected value and standard deviation also will be multiplied by r, and its CV will be unchanged. (Ott uses "expected value" for the mean.)

Statistical Formulae for Deriving Percentile Values

The 90th percentile value for a population can be derived in several ways. The set of FC counts collected at a site were subjected to a statistically-based formula (Zar, 1984). The estimated 90th percentile is calculated by:

(a) Calculating the arithmetic mean and standard deviation of the sample result logarithms (base 10);
(b) Multiplying the standard deviation in (a) by 1.28;

(c) Adding the product from (b) to the arithmetic mean;
(d) Taking the antilog (base 10) of the results in (c) to get the estimated 90th percentile.

The 90th percentile derived using this formula assumes a log-normal distribution of the FC data. Several sites were checked to verify log-normal distributions. The variability in the data is expressed by the standard deviation, and with some datasets it is possible to calculate a 90th percentile greater than any of the measured data.

Beales Ratio Equation

Beales ratio estimator from *Principles of Surface Water Quality Modeling and Control* by Thomann and Mueller (1987) provides a mass loading rate estimate of a pollutant. The formula for the unbiased stratified ratio estimator is used when continuous flow data are available for sites with less frequent pollutant sample data. The average load is then:

$$\overline{W}_p = \overline{Q}_p \cdot \frac{\overline{W}_c}{\overline{Q}_c} \cdot \left[\frac{1 + \left(\frac{1}{n} \right) \cdot \left(S_{QW} / \left(\overline{Q}_c \overline{W}_c \right) \right)}{1 + \left(\frac{1}{n} \right) \cdot \left(S_Q^2 / \overline{Q}_c^2 \right)} \right]$$

where,

$\overline{W}_p$ is the estimated average load for the period,
p is the period,
$\overline{Q}_p$ is the mean flow for the period,
$\overline{W}_c$ is the mean daily loading for the days on which pollutant samples were collected,
$\overline{Q}_c$ is the mean daily flow for days when samples were collected,
n is the number of days when pollutant samples were collected.

Also,

$$S_{QW} = [1 / (n-1)] * \left[\left(\sum_{i=1}^{n} Q_{ci} * W_{ci} \right) - n * \overline{W_c} \, \overline{Q_c} \right]$$

and

$$S^2_Q = [1 / (n-1)] * \left[\left(\sum_{i=1}^{n} Q_{ci}^2 \right) - n * \overline{Q_c^2} \right]$$

where,

Q_{ci} are the individually measured flows,
W_{ci} is the daily loading for the day the pollutant samples were collected.

Multiple Regression Model by Cohn (1988)

The method employs a statistical regression model, where the constituent concentrations are estimated based on streamflow and time/season. The application requires daily value streamflow records and unit values of constituent concentrations.

$$\ln[L] = \beta_0 + \beta_1 \ln[Q] + \beta_2 \ln[Q]^2 + \beta_3 T + \beta_4 T^2 + \beta_5 \mathrm{Sin}[2*\pi T] + \beta_6 \mathrm{Cos}[2*\pi T] + \varepsilon$$

where

L is the water quality constituent concentration (e.g., phosphorus, total suspended solids).
Q is the daily discharge.
T is time, expressed in years.

The parameters β_1 and β_2 in the equation correspond to variability related to flow dependence, the next pair correspond to time trends, and the third pair are used to fit a first-order Fourier series to the seasonal component of variability.

Appendix D. Marketing Elements for Water Quality Issues Evaluated by the TMDL Advisory Committee

Improving water quality conditions requires changing our behaviors that negatively affect our streams. In order to effectively change behaviors, it is important to identify the barriers and benefits to changing to the new behavior and the barriers and benefits to the current behavior. Agencies working to change behaviors need to increase the benefits of the desired behavior and reduce barriers preventing the adoption of the desired behavior. This is the basis for community-based marketing.

The Hangman Creek Advisory Committee applied these marketing principles to the water quality issues identified as affecting the streams in the Hangman Creek Watershed. For each of the issues, the current practice(s) and the desired practice(s) were identified. In general, the desired practice is a management practice that tends to improve water quality for the issue being discussed. Along with the desired practices, both barriers and benefits for continuing the current practices, and barriers and benefits for changing to the desired practices, were evaluated.

The barriers and benefits common to most of the issues and practices are listed below. There were several issues where the desired practice and current practice could be switched, depending on a person's point of view. It was recognized that most issues would benefit from continued, if not more, public education.

General benefits or motivations common to most ***desired practices*** were identified as:
- Improves water quality.
- Decrease any penalties associated with water quality violations.
- It is the right thing to do, may influence neighbors.

General costs or barriers common to most ***desired practices*** were identified as:
- Cost more money.
- Inconvenience, need more equipment or infrastructure.
- Increased maintenance.
- Takes land out of production.

General benefits or motivations common to most ***current practices*** were identified as:
- Easy, convenient.
- Costs less, cheaper.
- No government interference.
- More land in production, especially for leased land.

General costs or barriers common to most ***current practices*** were identified as:
- Possible fines, enforcement actions.
- Future regulations.
- Contributing to pollution.
- Missing opportunities for financial assistance.

The anticipated approaches to meet load allocations are outlined under Implementations Activities. The approaches that are expected to be used include the implementation of sediment reducing and livestock best management practices (BMPs), along with an information and education program. As incentive and implementation programs for BMPs are developed, large-scale programs will continue to assess the benefits of the implementation. Schedules and milestones for the implementation will be developed during the Detailed Implementation Plan formation.

Issue 1: Sediment/nutrients from agricultural operations

BMP	Parameters Addressed	Potential Problems to Implement BMP
No Till/ Minimum Till	Sediment Nutrients Turbidity	Equipment change, change in farm plans and practices, owner vs. leaser, initial decrease in yields, increase in chemical use, colder soil temperature, fields stay wetter.
Riparian Buffers	Sediment Nutrients Temperature DO	Loss of highly productive land, harder to farm, weed problems, costs in time and money to establish, potential wildlife fecal inputs.
Sediment Basins	Sediment Nutrients	Cost to install, need to be able to farm around, may need to clean out, small loss of farmland.
Grassed Waterway	Sediment Nutrients	Hay usually produces less return than other crops, maintenance, limited habitat, establishment time can be long.
Filter Strips	Sediment Nutrients Temperature	Reduces farmable land, weed problems, requires maintenance.
Divided Slopes	Sediment Nutrients	Harder to farm, may not work with all crops, increased turning time, pesticide and herbicide application harder.

Issue 2: Sediment/Fecal from Livestock and Wildlife

BMP	Parameters Addressed	Potential Problems to Implement BMP
Riparian Buffer	Sediment Nutrients Fecal	Requires new water access or source, more maintenance, weed problems.
Livestock Fencing	Sediment Nutrients Fecal	Requires new water access or source, more maintenance, potential problem during high water events.
Manure Retention Facilities	Nutrients Fecal	Initial costs, requires truck access and space may be a problem.
Off-Creek Watering	Sediment Nutrients Fecal	Need year round water source, may need numerous sources if lots of livestock, maintenance.
Intensive Management Grazing	Sediment Nutrients Fecal	Requires more land.
Nutrient/fecal Management	Sediment Nutrients Fecal	Requires soil testing, may require more equipment.

Issue 3: Nutrients/Chemicals from Residential uses

BMP	Parameters Addressed	Potential Problems to Implement BMP
Fertilizer Management	Nutrient	Need better education at local level.
Septic Maintenance	Nutrients Fecal	Increased maintenance costs.
Pet waste Management	Nutrients Fecal	Need to have bags along when walking pets, need a place to put waste.
Proper Household Chemical Use and Disposal	Chemicals Nutrients	Need local recycle centers where hazardous household waste can be taken.
Proper Pesticide/Herbicide Use and Disposal	Chemicals Nutrients	Need local recycle centers where hazardous household waste can be taken.
No Lawn Clipping Dumping in Streams	Chemicals Nutrients	Need another way to compost or dispose of yard waste.
Follow Shoreline Management	Sediment Chemicals Nutrients	Less access to the water, loss of view, weed problems.

Issue 4: Sediment from Agricultural Field Ditches

BMP	Parameters Addressed	Potential Problems to Implement BMP
Uphill Plowing	Sediment Nutrients	Uses more fuel, harder to plow.
Ditch Maintenance	Sediment Nutrients	Increased time and costs.
Proper Construction/ Engineering	Sediment Nutrients	Dependent on upstream land uses remaining the same over time, may require assistance from NRCS or conservation district.
Grassed Waterway Conversion	Sediment Nutrients	Could take more land out of primary production.

NRCS = Natural Resources Conservation Service

Issue 5: Nutrients/fecal from Improper Functioning Septic Systems

BMP	Parameters Addressed	Potential Problems to Implement BMP
Educate on the negative effects of garbage disposals	Fecal Chemicals Nutrients	Desired in kitchens, may already exist
Have system inspections every 1-3 year	Fecal Chemicals Nutrients	Cost of inspection/pumping done on a regular basis. Need to target older systems near streams.
Take roof drains out of system/away from drainfield	Fecal Chemicals Nutrients	May not have a good area to drain roof system to.
Educate about proper items to go into systems	Fecal Chemicals Nutrients	Reaching people with septic systems, not enough places for disposal of household hazardous wastes.
Comment on new developments through SEPA	Fecal Chemicals Nutrients	SCCD may not be on all lists for review. Public may not be aware of opportunity to comment.
Replace or repair failing systems	Fecal Chemicals Nutrients	High cost, many people may not know systems need to be replaced.

SCCD = Spokane County Conservation District
SEPA = State Environmental Protection Act

Issue 6: Sediment from Gravel and Summer Roads

BMP	Parameters Addressed	Potential Problems to Implement BMP
Pave Roads	Sediment	Initial cost to pave and maintenance.
Close Roads in Winter	Sediment	Less access to fields, may require gates on roads, more maintenance.
Increased Grading and graveling	Sediment	Increased costs for the county.

Issue 7: Sediment from Sheer or Undercut Banks

BMP	Parameters Addressed	Potential Problems to Implement BMP
Live Plantings	Sediment Erosion Temperature	Not an instant fix, may need time to fully develop, requires maintenance.
Reshape Bank and Plantings	Sediment Erosion Temperature	Increased cost, must remove cut bank material from flood plain, erosion potential for first few years, loss of land.
Engineered Structures	Sediment Erosion	Provides less habitat, cost more to install, need permits.

Issue 8: Sediment from Storm Water

BMP	Parameters Addressed	Potential Problems to Implement BMP
Road Runoff to Basin	Sediment Chemicals	Increased cost, increase land use near roads, maintenance of ditches.

Issue 9: Forestry Management

BMP	Parameters Addressed	Potential Problems to Implement BMP
Selective Harvest	Sediment	Less income, need skilled logger, may be topography dependent.
Stream Crossings	Sediment	Cost more, may need to remove after completion.
Streamside Management Zones	Sediment Temperature	Less trees available for logging, harder to remove logs.
Proper Road Planning and Construction	Sediment	May take longer to plan, could increase road costs.

Issue 10: Sediment from Roadside Ditching

BMP	Parameters Addressed	Potential Problems to Implement BMP
Design Vegetated Ditches	Sediment Chemicals	Weed problems may need maintenance of vegetation, may need more space to install, some engineering required.
Install Detention Basins	Sediment Chemicals	Weeds problems may need maintenance, some engineering required.

Appendix E. Response to Public Comments

This appendix will be completed after the Public Comment period.